MEMORANDUM REPORT ARBRL-MR-03204

AUTOMATIC PLOTTING ROUTINES FOR ESTIMATING AERODYNAMIC PROPERTIES OF SPIN STABILIZED PROJECTILES IN FLAT FIRE TRAJECTORIES AT 2<M<5

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October 1982

US ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
BALLISTIC RESEARCH LABORATORY
ABERDEEN PROVING GROUND, MARYLAND

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19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

Aerodynamic coefficients
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Flat fire trajectory
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Retardation

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)* jmk

A predictive program for the estimation of aerodynamic coefficients of spin stabilized projectiles for flat fire at 2<M<5 is presented in desk top (Tektronix 4051) computer context. The technique is demonstrated by application to a typical projectile for which range data is available for comparison.

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I. INTRODUCTION

Ballistic projectiles intended for employment against low flying aircraft are characterized by a very short time of flight, which implies a flat trajectory and maximum target penetration/capture coupling. Current gun technology permits typical launch velocities to M = 5 and anticipated target defense appears impervious to penetration below M = 2. The long rod penetrator has limited applicability in this instance, being expected to pass through the target completely. Thus the projectile of interest is spin stabilized and operates at 2<M<5; and the challenge of design lies in our ability to predict the aerodynamic behavior of classical shell in this environment.

Various analytic and empirical determinations of aerodynamic characteristics of spin stabilized projectiles are found in open literature[1-5] where selected characteristics of the overall flight performance are considered in detail. The predictions of drag coefficient tend to be substantiated by test results while the estimates of static moment, reported less frequently, are usually found more difficult to verify. Generalized techniques to predict the damping moment and Magnus moment coefficients are seldom explored although extensive range data has been accumulated.

R.L. McCoy[1] has presented an authoritative treatise on calculating drag coefficient and R.H. Whyte[2] has published reliable data on the static moment coefficient. Historically, H.P. Hitchcock[3] has proposed a set of correlations of test results while Reference 4 provides an extensive bibliography with "how to" examples. A current analysis of the flow field around the typical projectile is demonstrated by W.B. Sturek, et. al.,[5,6] by means of a three-dimensional finite difference algorithm where the damping and Magnus contributions are explicitly determined. These programs are available in the FORTRAN programming.

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[1] *R.L. McCoy, "McDrag" - A Computer Program for Estimating the Drag Coefficients of Projectiles," BRL Report No. ARBRL-TR-02293, February 1981 (AD #A098110).*

[2] *R.H. Whyte, "Spinner" - A Computer Program for Predicting the Aerodynamic Coefficients of Spin Stabilized Projectiles," General Electric Technical Report TIS69APB3, 1969.*

[3] *H.P. Hitchcock, "Aerodynamic Data for Spinning Projectiles," Ballistic Research Laboratories Report No. 620, October 1947. (AD #800469).*

[4] *AMCP 706-242, "Design for Control of Projectile Flight Characteristics," 1966.*

[5] *W.B. Sturek, D.C. Mylin and C.C. Bush, "Computational Parametric Study of the Aerodynamics of Spinning Slender Bodies at Supersonic Speeds," AIAA-80-1585-CP, August 1980.*

[6] *W. B. Sturek, D. C. Mylin, "Computational Parametric Study of the Magnus Effect on Boattailed Shell at Supersonic Speeds, AIAA-81-1900, August 1981.*

The present report offers a simplified procedure to estimate values of the initial aerodynamic design parameters required for flat fire trajectory specification within 2<M<5. Execution is by means of a desk-top computer program for application into the Tektronix 4051 computer and is suited for conversion to any comparable machine. It requires only the geometry and physical properties of the projectile and presents the dimensional outline, a complete tabulation of the aerodynamic coefficients and a graphical exposition of the summarized results. The aerodynamic basis is wholly empirical.

II. PROCEDURE

Reference 7 contains a collection of range data on a wide variety of projectiles which were fired in the BRL Aerodynamics Range. The maximum diameter of the projectiles extends to 20 mm and the geometry includes nose shapes of circular arc and conical development, variations in length of nose and afterbody, boat tail proportion and rotating bands. Figure 1 shows a line drawing of a typical projectile. Associated performance curves[7] allow an insight into the effects of these variables through the supersonic flow region and permit the formulation of the equations proposed by this report as presented in Tables 1, 2, 3 and 4. One exception is that normal force and static moment data for conical nosed, boattailed projectiles are not available although the square based data is included. The performance curves are not fitted statistically since the survey data do not include discrete numerical information nor do they indicate error bounds. However, the resulting algebraic expressions appear to be consistant and reasonable within the indicated Mach excursion. Table 5 lists the equations of the gyroscopic stability factor, the initial yaw period[8] and the velocity decrement[9]. The normalized caliber notation, where a representative linear dimension provides a reference length and the mass/force dimension is converted to a specific gravity, is employed throughout, except that the trajectory range is given metric expression.

A complete program listing with initialization instructions is presented in Appendix A. By command print-out, the program provides

- An outline plot of the projectile.
- A complete tabulation of aerodynamic coefficients.
- Individual graphs of the drag, normal force, static moment, damping moment and Magnus moment slopes versus Mach number.
- A graph of velocity versus range with annotated schedule of retardation.
- The length of the initial yaw cycle and a determination of the gyroscopic stability factor.

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[7] *W.F. Braun, "Aerodynamic Data for Small Arms Projectiles," Ballistics Laboratories Report 1630, January 1973, (AD #909757L).*

[8] *C.H. Murphy, "Free Flight Motion of Symmetric Missiles," BRL Report No. 1216, July 1963 (AD #442757).*

[9] *W.F. Donovan, "Simplified Determination of Retardation for Kinetic Energy Projectiles," BRL Memorandum Report No. ARBRL-MR-02994, February 1980 (AD # 086095).*

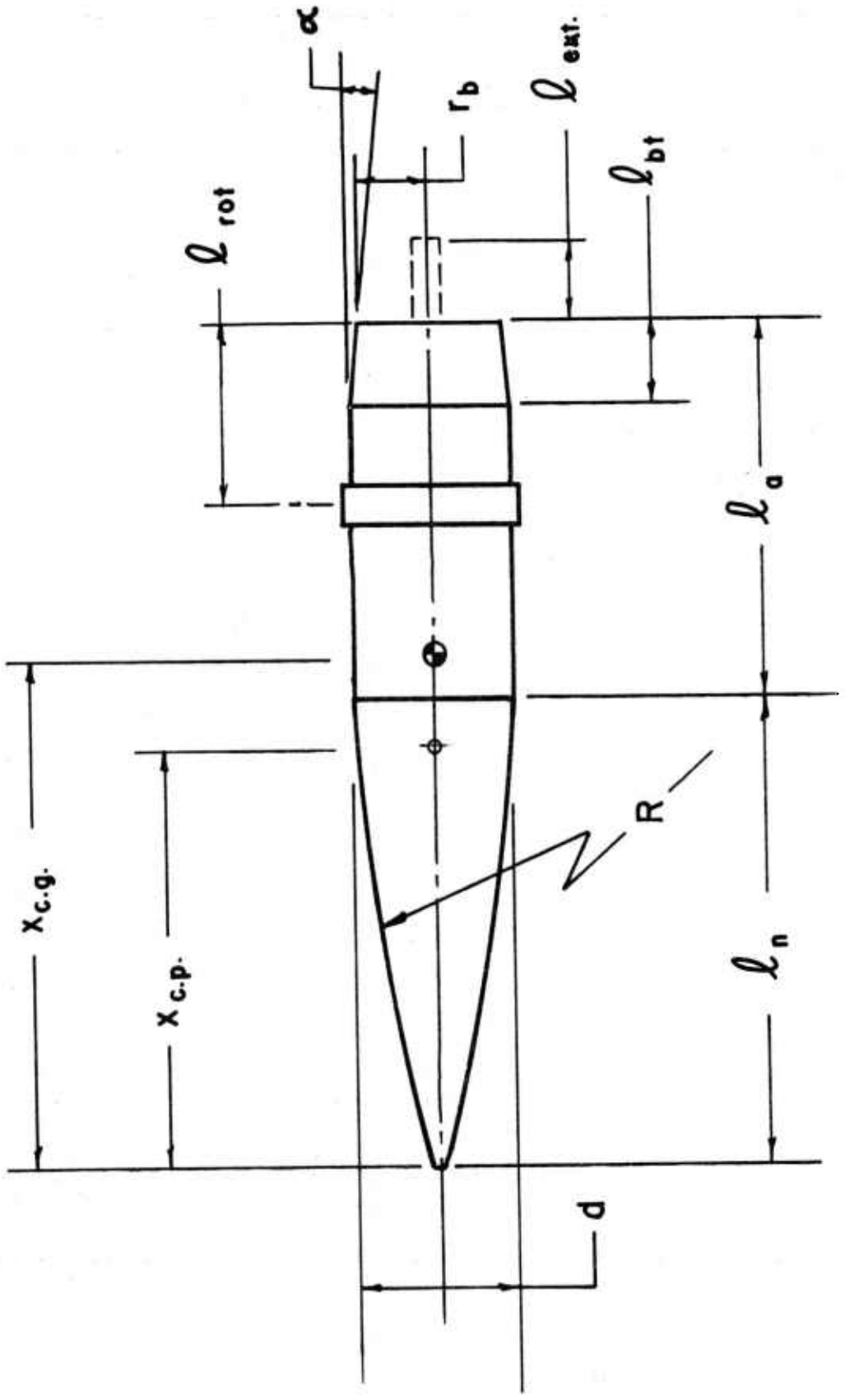

Figure 1. Outline of Typical Projectile

TABLE 1. DRAG COEFFICIENT EQUATIONS

Projectile Nose	Drag Component	Description	Computer Code
Ogive	C_{DWB}	$.312\ M^{-.53}\ell_n^{-.28}$	C_1
	C_{DVB}	$(.15 - .03M + .01M^{-1} + .0001M^{3.6})(.083\ell_a + .0625\ell_n)(M^{-1})[(30)^{4.6/R}]$	C_2
	C_{DBB}	$(.53 - .08M)(r_b)^2$	C_3
	C_{DRB}	.015	C_4
	C_{DT}	$C_{DWB} + C_{DVB} + D_{DBB} + C_{DRB}$	C
Conical	C_{DWB}	$.4\ M^{-.53}\ell_n^{-.28}$	C_1
	C_{DVB}	$(.15 - .03M + .01M^{-1} + .0001M^{3.6})(.083\ell_a + .0625\ell_n)(M^{-1})$	C_2
	C_{DBB}	$(.53 - .08M)(r_b)^2$	C_3
	C_{DRB}	.015	C_4
	C_{DT}	$C_{DWB} + C_{DVB} + D_{DBB} + C_{DRB}$	C

TABLE 2. NORMAL FORCE SLOPE COEFFICIENT EQUATIONS

Projectile Nose	Base	$C_{N\alpha}$	Description	Computer Code
Ogive	Square	$C_{N\alpha SQ}$	$[.7456 - .2774(\exp^{-.0558M})][\log(.0307R) + 1]$ $[49.296M^{.594} - \log(.0307R)][\log(2.61M^{-1})]$ $[.8594(\exp^{.084M})\ell_n{}^{-.217} R^{-.783}{}_M{}^{-.518}]$	H
	Boat-tail	$C_{N\alpha BT}$	$C_{N\alpha SQ} + .15 - .046M^{.5} + [7M^{.5}R^{-1}][\log(7R^{-1})]$	H + H1
	Boom	$C_{N\alpha}ext$	$C_{N\alpha BT}(1.24 - .071M)\ell_{ext}$	H2
Cone	Square	$C_{N\alpha SQ}$	$\ell_n(.54 + .01M) - \ell_a (.015-.02M)$	N1

TABLE 3. STATIC MOMENT SLOPE COEFFICIENT EQUATIONS

Projectile Nose	Base	$C_{M\alpha}$	Description	Computer Code
Ogive	W/o extension	$C_{M\alpha}$	$[C_{N\alpha}][c.g. - \{2.061 + .266 \log M + \log(R/32.5)\ [.538 - .063 \log M + .033 \times \log (M^2)] - .278M^{.75} + .08 \tan\lambda\}$	
	W/ extension	$C_{M\alpha(ext)}$	$[C_{N\alpha}][c.g. - \{3.926 + .506 \log M + \log(R/32.5)\ [1.021 - .318 \log M + .2(\log M)(\log M)]\}\ \{.6656 - .0857\ell_{ext} + (\ell_{rot}/R)(3.8-1.05M)\} + M/R - .02 \tan\gamma]$	NØ
Conical	Square	$C_{M\alpha}$	$[C_{N\alpha}][c.g. - .67\ell_n - .0075M + .05\ell_a M)$	NØ

TABLE 4. DAMPING MOMENT AND MAGNUS MOMENT SLOPE EQUATIONS

Projectile Nose	Coefficient	Description	Computer Code
Ogive and Conical	$C_{Mq} + C_{M\alpha}$	$(.166M - .966)\ell_n - (.237M + 1.91)\ell_a - .123R$	M1
	$C_{Mp\alpha}$	$(.107 - .01M)\ell_n + (.0375 - .002M)\ell_a$	M2

TABLE 5. TRAJECTORY PARAMETERS

Projectile Nose	Trajectory Parameter	Description	Computer Code
Ogive and Conical	Gyroscopic Stability Factor	$\frac{(I_x)^2\ 2\ (pd/v)^2}{\pi\ \rho\ I_y\ C_{M\alpha}\ d^5}$	S
	Initial Yaw Period	$\frac{2\ \pi\ d}{\left[\left(\frac{I_x}{I_y}\right)^2\left(\frac{pd}{v}\right)^2 - \frac{\pi\rho d^5}{2\ I_y}\left(C_{M\alpha}\right)\right]^{\frac{1}{2}}}$	S1
	Mach Number Along Range	$\frac{b}{Pexp^{Qs} - c}$	V
	Average Velocity Decrement	$\frac{M_0 - M}{s}\ (v)_{sonic}$	J2

III. RESULTS

With test data to M = 3.2, the HS831-L projectile as described by Neitzel[10] is used to demonstrate the working procedure. The computer program (Appendix A) lists the input, Table A, and also develops the output according to the following schedule.

Figure No.	Description
2	Projectile Outline
(Table 6)	Table of Aerodynamic Coefficients vs M
3	C_{DT} vs M
4	$C_{N\alpha}$ vs M
5	$C_{M\alpha}$ vs M
6	$C_{Mq}+C_{M\dot{\alpha}}$ vs M
7	$C_{Mp\alpha}$ vs M
8	Trajectory Parameters

Test values from Reference 10 are superposed on the graphs by asterisks. The predictive code indicates conservative values for this projectile.

IV. CONCLUSIONS

With the facility of the developed programs as employed by the desk-top computer, the design problem of estimating values of the aerodynamic coefficients and trajectory parameters for spin-stabilized shell in flat fire is considerably simplified. Individual effects of geometric modification of a particular candidate projectile can be determined immediately. Expertise in the science of fluid mechanics is not required to produce rational results, simple constraining criteria being sufficient for initial considerations.

Although a number of projectiles has been examined by these programs, only the M-392[11] and those of Reference 5 show data beyond M = 3.6. The M-392 is unusual in that a base stub is attached (Appendix B) while the Reference 5 models, Appendix C) are precision manufactured for wind tunnel study. Neither carries a rotating band.

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[10] *G.P. Neitzel, Jr., "Aerodynamic Characteristics of 30 MM HS831-L Ammunition Used in the British 30 M Rarden Gun," Ballistic Research Laboratories Memorandum Report 2466, March 1975 (AD #B003939L)*

[11] *E.M. Schmidt, B.P. Burns and G. Samos, "Replica Modeling of the Launch and Flight Aerodynamics of Projectiles," BRL Report No. ARBRL-TR-02104, September 1978 (AD # A063521).*

The M-392 determinations are included, although these represent a unique projectile, to indicate the very strong effect of the base stub on the normal force and static moment development. If this constitutes a general behavior pattern, and such a conclusion requires correlating verification, the phenomenology must be examined by analytical techniques.

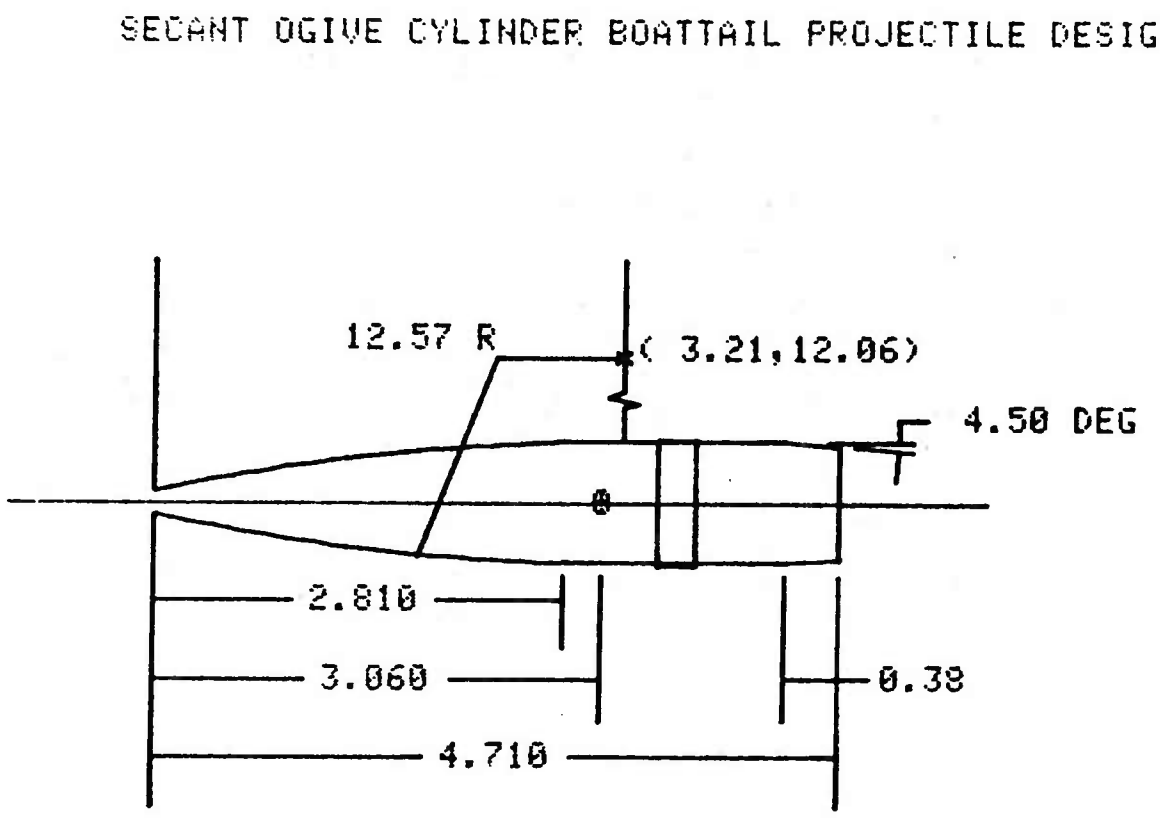


Figure 2. Outline of HS831-L Projectile

ALL VALUES ARE IN CALIBERS UNLESS OTHERWISE NOTED

```
B4      OGIVE LENGTH:  2.81
B5      OGIVE RADIUS: 12.57
D       CYLINDRICAL BODY LENGTH:  1.52
LS      CENTER OF GRAVITY OF PROJECTILE (NOSE):  3.07
B3      BOATTAIL LENGTH:  0.38
D2,D1   BOATTAIL ANGLE (DEGREES,MINUTES):  4.75
B6      ROTATING BAND RADIUS:  0.52
D3      ROTATING BAND WIDTH:  0.25
L7      DISTANCE TO ROTATING BAND FROM BASE:  1.01
L1      LENGTH OF BOOM EXTENTION:  0.00
I1      AXIAL MOMENT OF INERTIA (CAL↑5):    1.91
I2      TRANSVERSE MOMENT OF INERTIA (CAL↑5):   15.20
M5      WEIGHT OF PROJECTILE (CAL↑3):   13.52
N       TWIST OF PROJECTILE (NO. OF CAL/REV): 30.00
D6      DIAMETER OF PROJECTILE (MM): 29.900
R0      DENSITY OF AIR (g/cc): 0.001225
M0      MUZZLE MACH NUMBER:  4.50
S3      MAXIMUM RANGE OF PROJECTILE (METERS,<=4000): 4000
A       PLOTTING DEVISE (1=PEN PLOTTER, 32=SCREEN):  32
```

TABLE 6. AERODYNAMIC COEFFICIENTS FOR SPIN STABILIZED PROJECTILES

AERODYNAMIC COEFFICIENTS FOR SPIN STABILIZED PROJECTILES

	MACH NUMBER						
	2.0	2.5	3.0	3.5	4.0	4.5	5.0
CDWB	0.162	0.144	0.131	0.120	0.112	0.105	0.100
CDVB	0.056	0.038	0.026	0.019	0.014	0.010	0.008
CDBB	0.081	0.072	0.064	0.055	0.046	0.037	0.029
CDRB	0.015	0.015	0.015	0.015	0.015	0.015	0.015
CDT	0.314	0.269	0.236	0.209	0.187	0.168	0.151
CNA$0	3.058	3.213	3.362	3.510	3.658	3.808	3.959
CNABT	2.681	2.775	2.868	2.964	3.064	3.168	3.278
CNABE	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CNAT	2.681	2.775	2.868	2.964	3.064	3.168	3.278
Cmq+Cm`a	-7.857	-7.849	-7.841	-7.833	-7.825	-7.817	-7.809
CNPA	0.316	0.300	0.284	0.268	0.252	0.236	0.220
CP(NOSE)	1.812	1.947	2.069	2.180	2.283	2.380	2.473
CMA	3.383	3.126	2.883	2.650	2.423	2.197	1.971

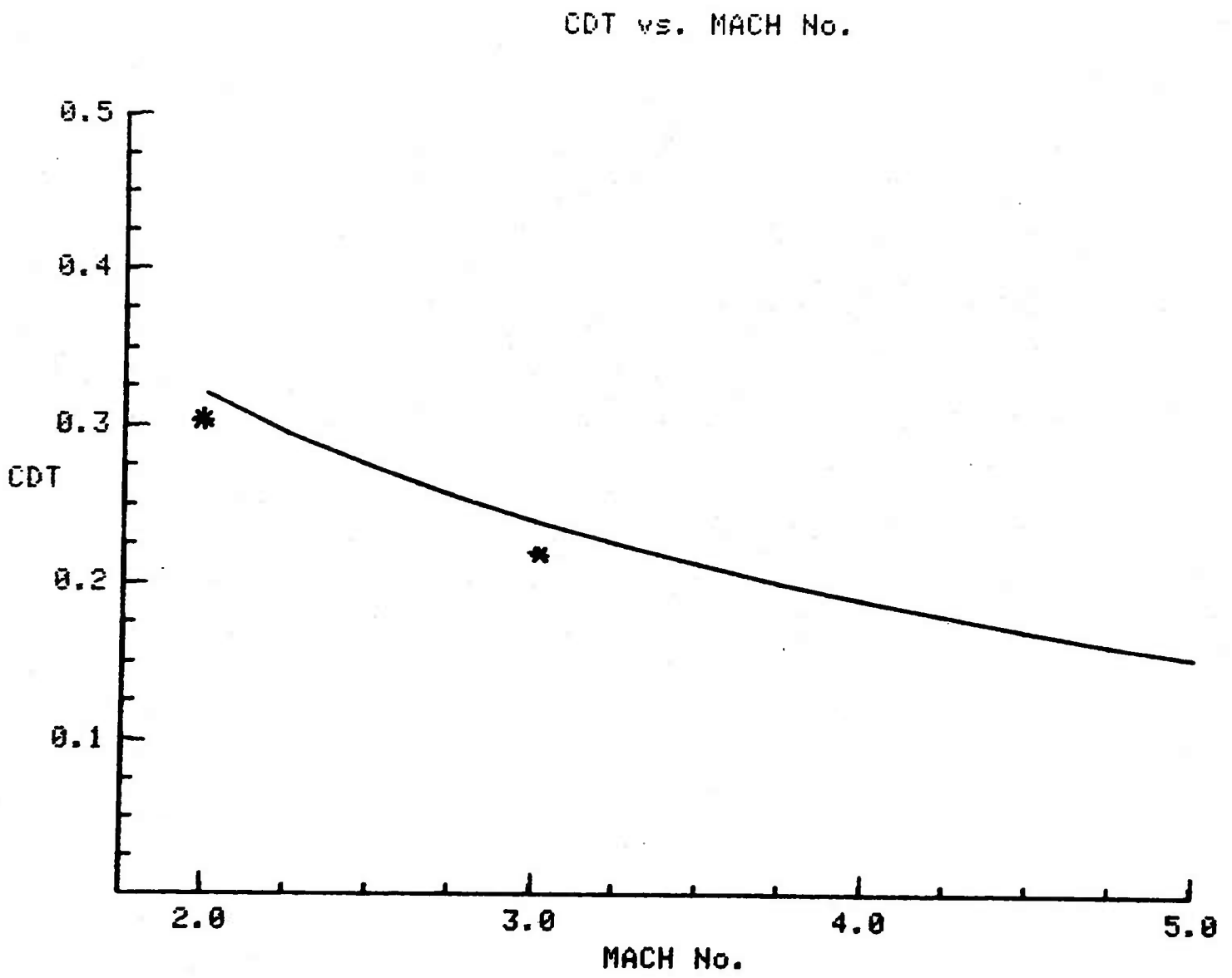


Figure 3. Zero Yaw Drag Coefficient vs Mach Number

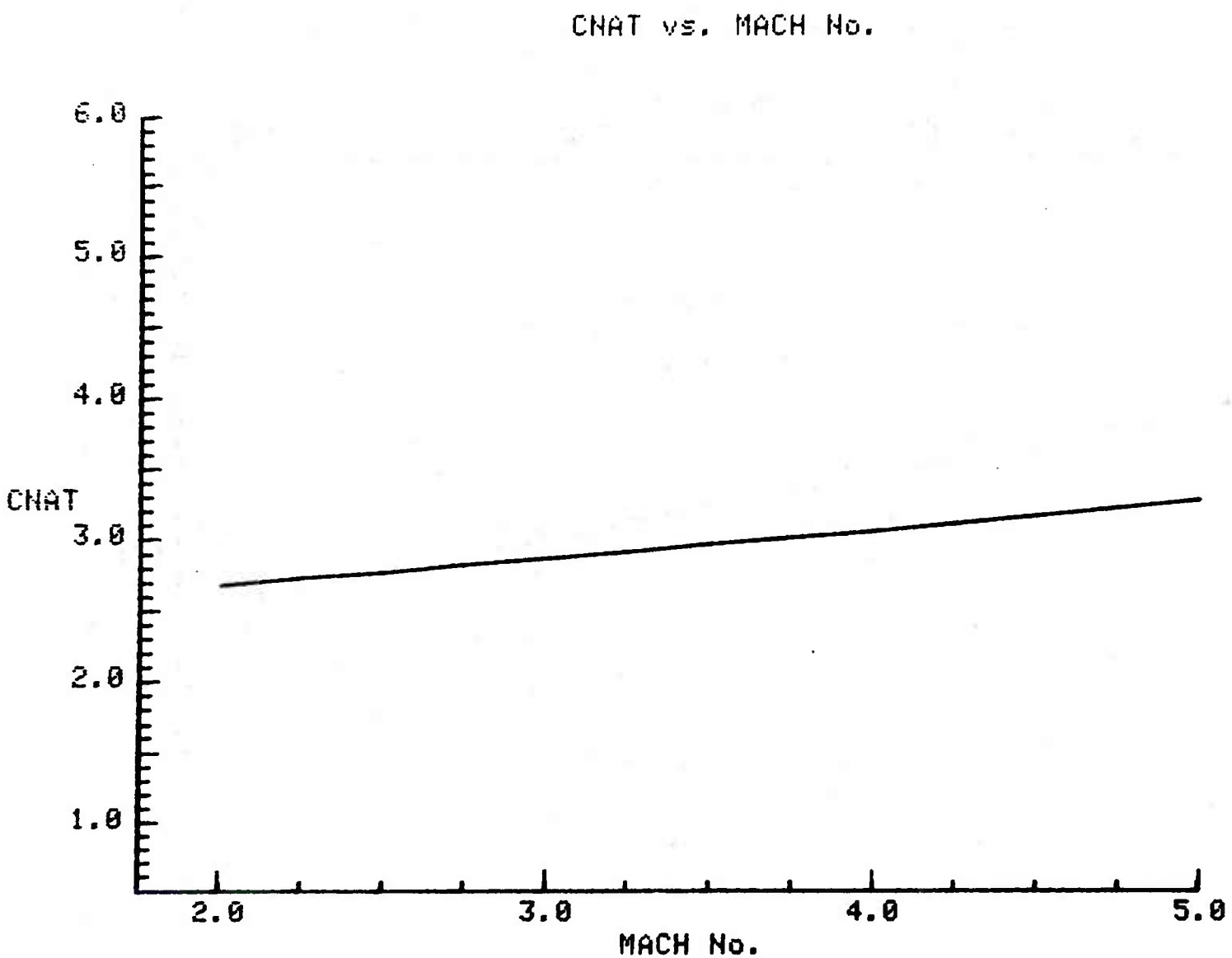


Figure 4. Normal Force Slope Coefficient vs Mach Number

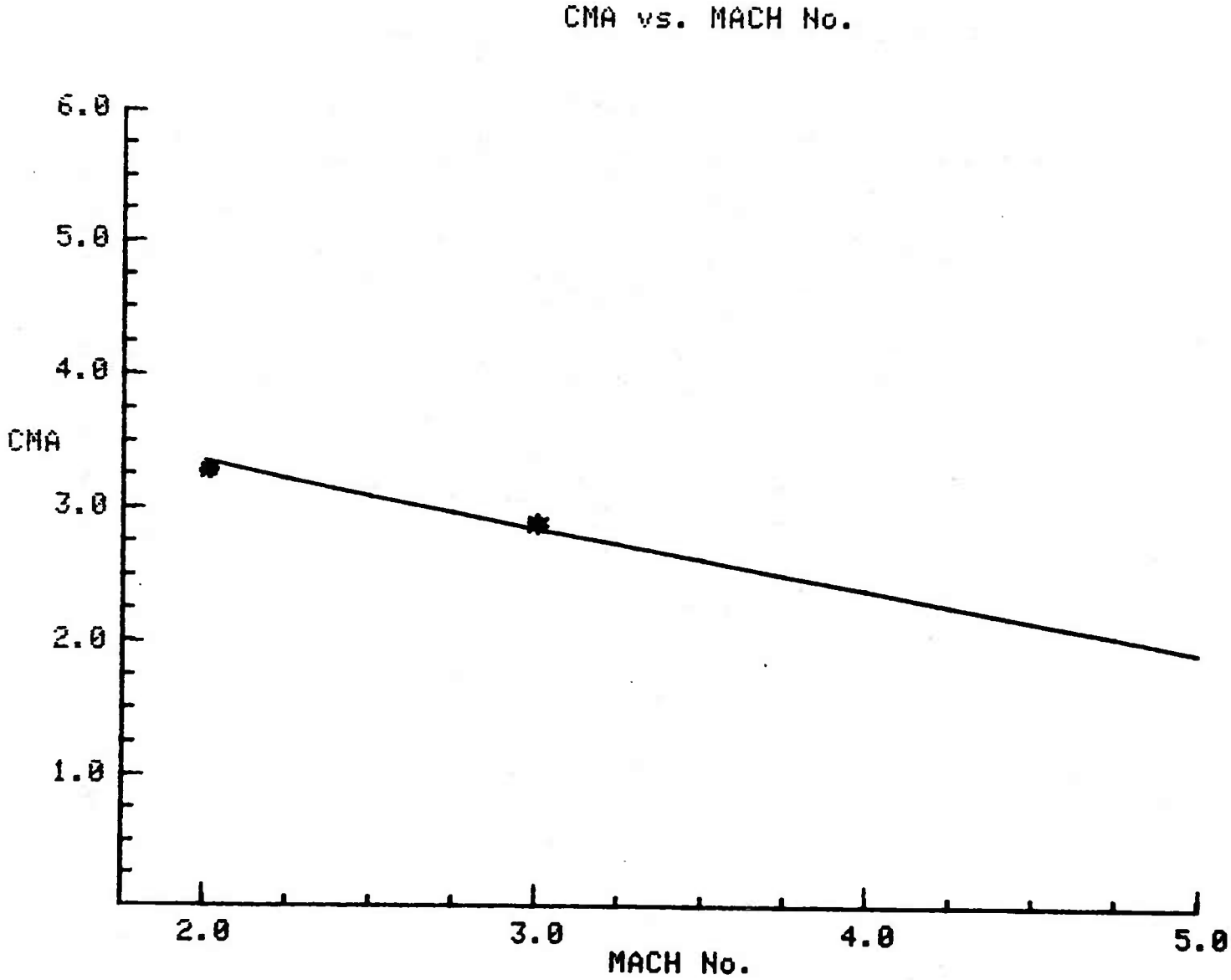


Figure 5. Static Moment Slope Coefficient vs Mach Number

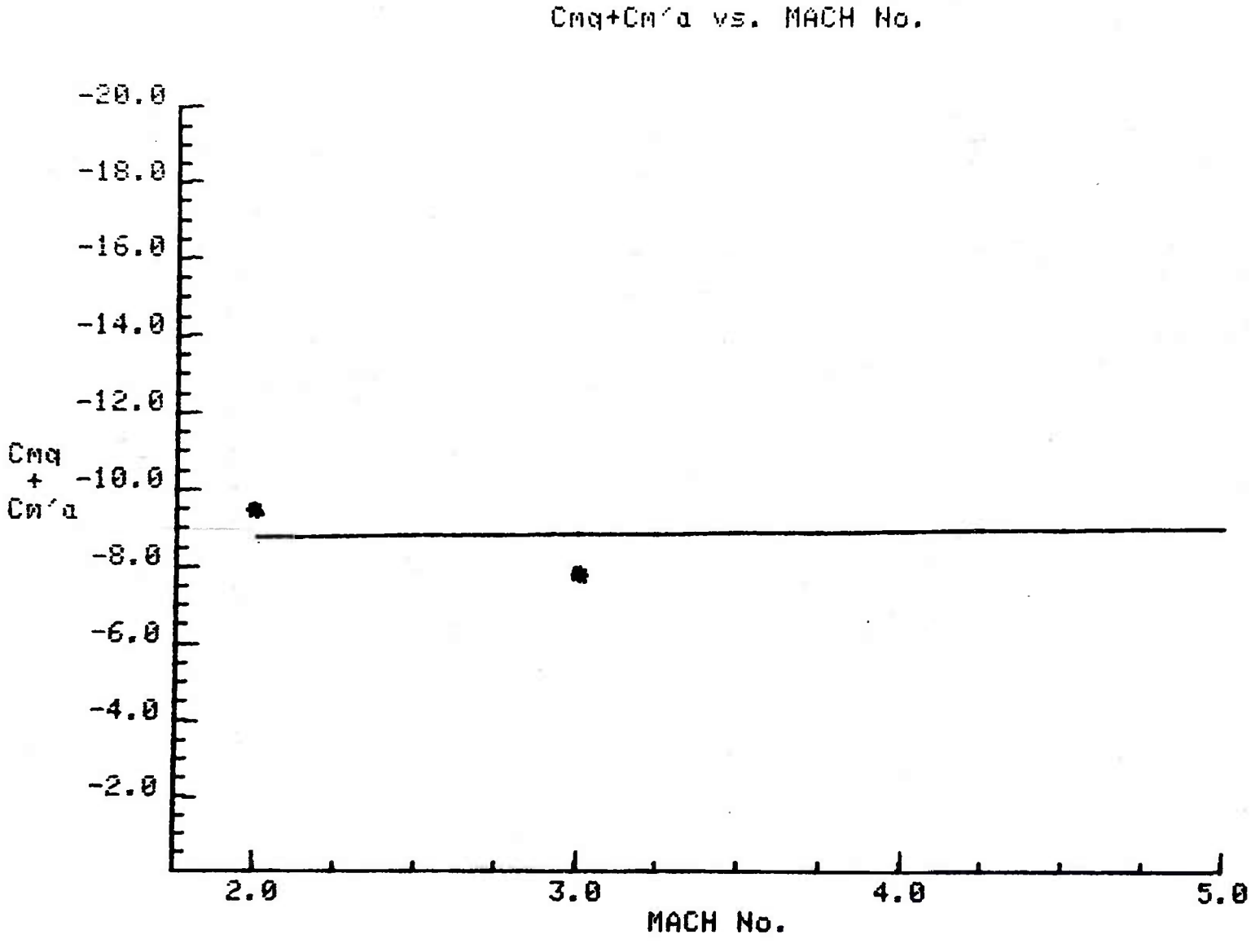


Figure 6. Damping Moment Slope Coefficient vs Mach Number

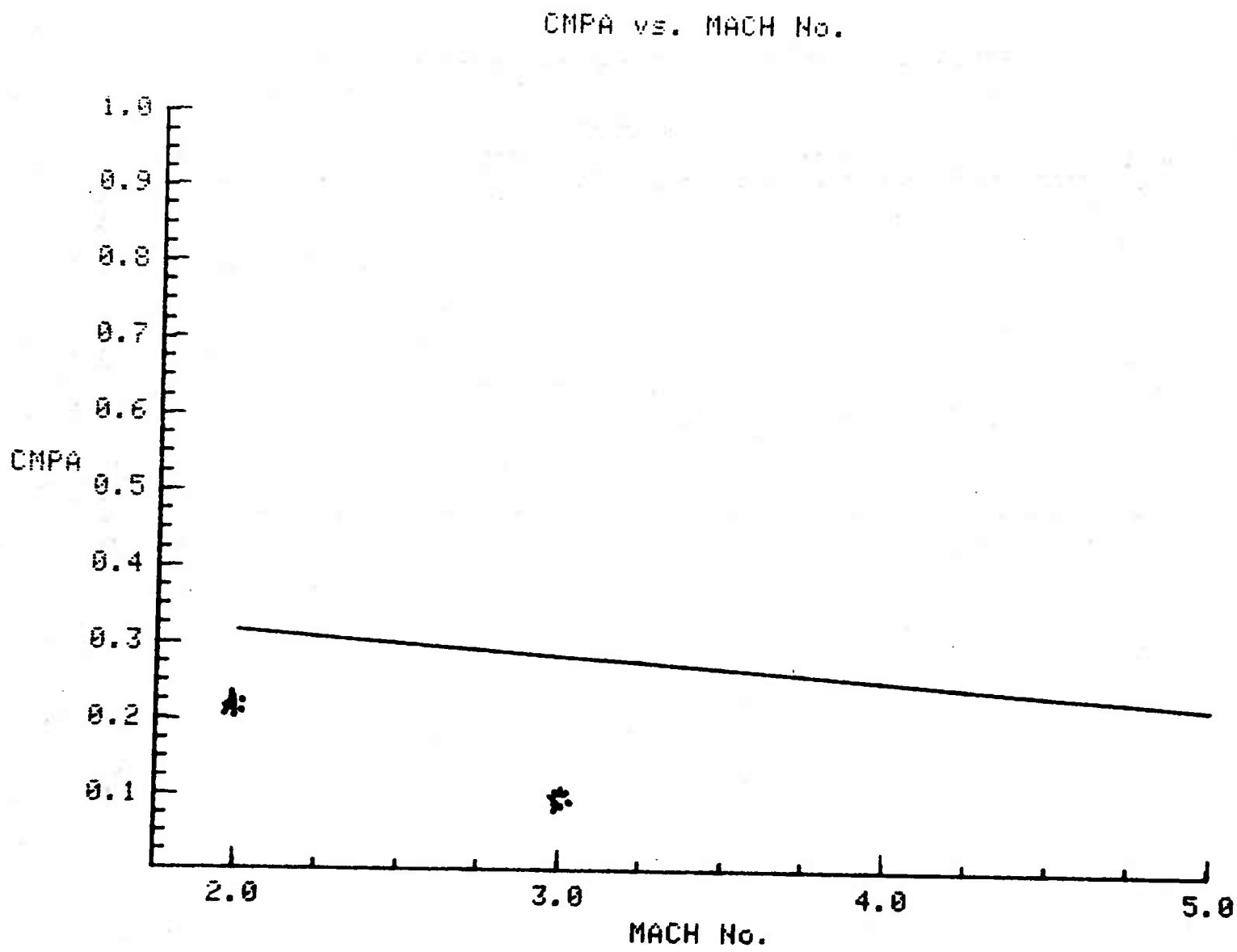
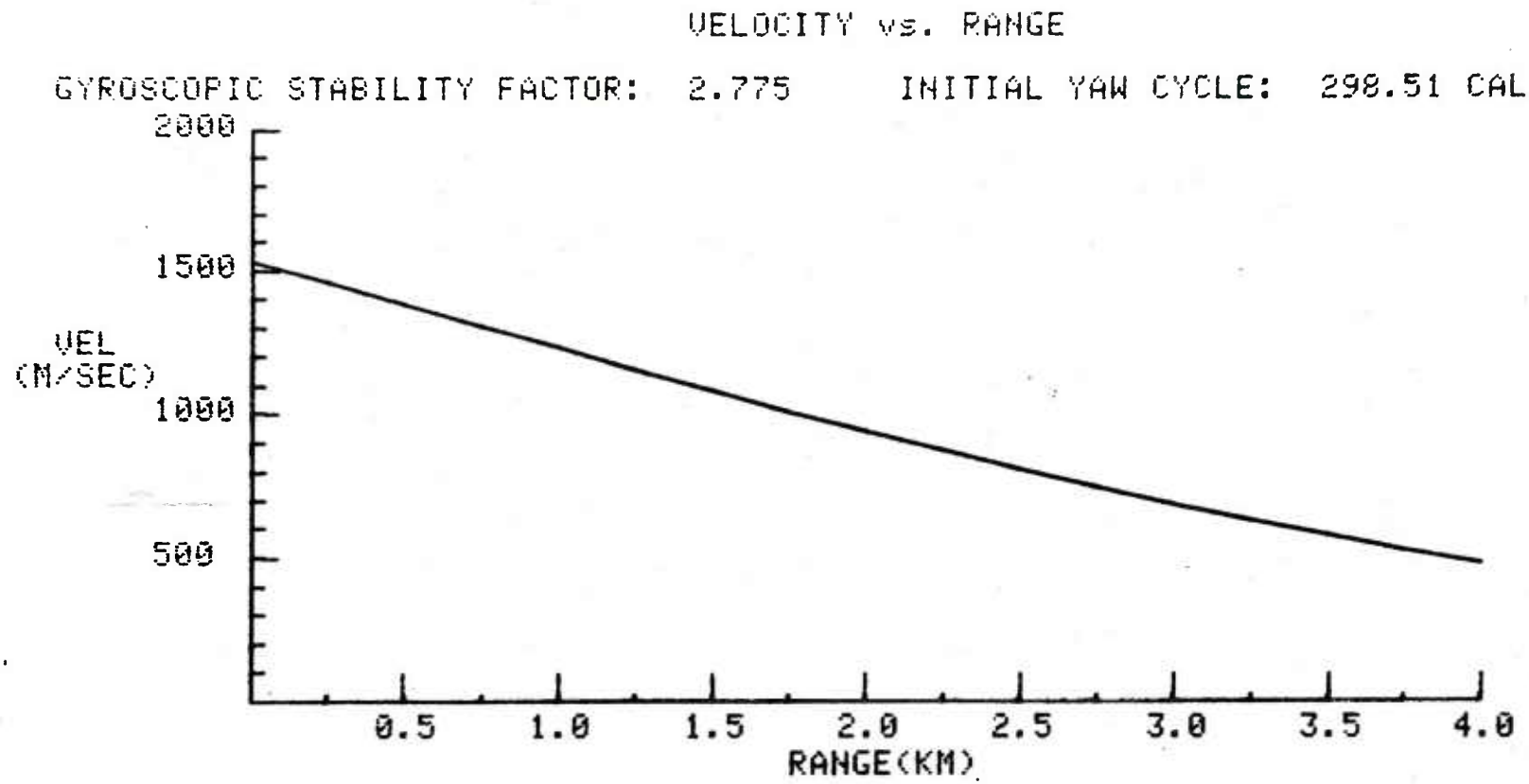


Figure 7. Magnus Moment Slope Coefficient vs Mach Number



RANGE:	4000 KM	RETARDATION:	263.008 (M/S)/KM
RANGE:	3500 KM	RETARDATION:	273.174 (M/S)/KM
RANGE:	3000 KM	RETARDATION:	282.335 (M/S)/KM
RANGE:	2500 KM	RETARDATION:	290.079 (M/S)/KM
RANGE:	2000 KM	RETARDATION:	295.998 (M/S)/KM
RANGE:	1500 KM	RETARDATION:	299.737 (M/S)/KM
RANGE:	1000 KM	RETARDATION:	301.034 (M/S)/KM
RANGE:	500 KM	RETARDATION:	299.760 (M/S)/KM
RANGE:	0 KM	RETARDATION:	298.161 (M/S)/KM

Figure 8. Trajectory Parameters

REFERENCES

1. R.L. McCoy, "McDrag" - A Computer Program for Estimating the Drag Coefficients of Projectiles," BRL Report No. ARBRL-TR-02293, February 1981 (AD #A098110).

2. R.H. Whyte, "Spinner" - A Computer Program for Predicting the Aerodynamic Coefficients of Spin Stabilized Projectiles," General Electric Technical Report TIS69APB3, 1969.

3. H.P. Hitchcock, "Aerodynamic Data for Spinning Projectiles," Ballistic Research Laboratories Report No. 620, October 1947. (AD #800469).

4. AMCP 706-242, "Design for Control of Projectile Flight Characteristics," 1966.

5. W.B. Sturek, D.C. Mylin and C.C. Bush, "Computational Parametric Study of the Aerodynamics of Spinning Slender Bodies at Supersonic Speeds," AIAA-80-1585-CP, August 1980.

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11. E.M. Schmidt, B.P. Burns and G. Samos, "Replica Modeling of the Launch and Flight Aerodynamics of Projectiles," BRL Report No. ARBRL-TR-02104, September 1978 (AD # A063521).

APPENDIX A

INITIALIZATION INSTRUCTIONS

(1) The program is stored using three files of a magnetic tape cartridge intended for use on a Tektronix 4051 desk-top minicomputer. To begin program execution, press the "autoload" button or use the dual commands of "Find 1" followed by "Old". It will take approximately 15 seconds to load the first program and from this point on, the user is guided through the program by a number of questions.

(2) The program consists of two main subprogram files, one for the conical nose shape and the other for the ogival nose shape. The user is asked the desired shape and is taken to the respective file. Both subprograms offer identical menus but involve different calculations.

(3) A maximum of 20 physical parameters is required for program execution. All such parameters must be input in calibers with a few noted exceptions. These parameters are requested as follows:

a) nose length
b) length of radius
c) cylindrical body length
d) boattail length
e) boattail angle
* f) radius of curvature offset
g) rotating band radius
h) rotating band width
i) distance from rotating band center to base of projectile
j) length of boom extension

*--Only required for ogival nose

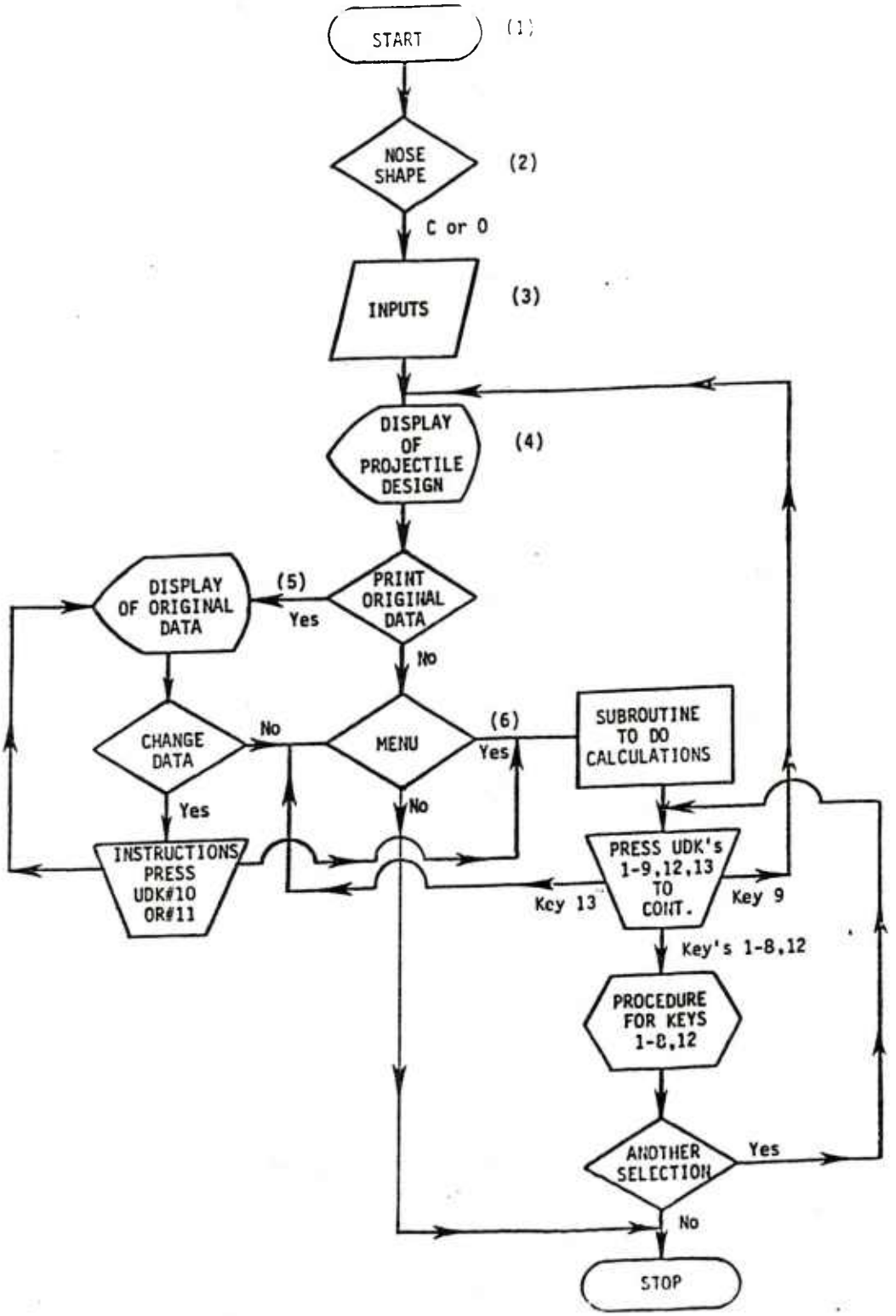
The graph of velocity versus range requires eight additional input parameters. Because this graph is not always desired, receiving it is optional to the user. The additional parameters are requested as follows:

a) axial moment of inertia
b) transverse moment of inertia
c) weight of projectile
d) twist of projectile
e) diameter of projectile in millimeters
f) air density
g) muzzle Mach number
h) maximum range of projectile desired.

Both subprograms use thirteen User Definable Keys. These thirteen selections are listed below.

1...Nomenclature
2...Table of Aerodynamic Coefficients
3...Total Drag Coefficient (C_{D_t}) versus Mach Number Plot
4...Total Normal Force Slope Coefficient ($C_{N\alpha_t}$) versus Mach Number Plot
5...Static Moment Slope Coefficient $C_{M\alpha}$) versus Mach Number Plot
6...Damping Derivative Slope Coefficient ($C_{M_{\dot{\alpha}}}+C_{M\alpha}$) versus Mach Number Plot
7...Magnus Moment Slope Coefficient ($C_{M\rho\alpha}$) versus Mach Number Plot
8...Velocity versus Range Plot, Gyroscopic Stability Factor, Initial Yaw Cycle, Retardation at different range values

9...Return to original spin stabilized projectile design
10...Views the initial data (see (5))
11...Calculates data (see (5))
12...Prepares the user to view another projectile shape
13...Returns user to menu



Flowchart for Automatic Plotting Routines

```
100 PAGE
110 PRI "THIS PROGRAM WILL CALCULATE AND PLOT ESTIMATED STATIC AERODY";
120 PRINT "NAMIC"
130 PRINT "COEFFICIENTS FOR SPIN STABILIZED PROJECTILES FOR 2<M<5."
140 PRINT
150 PRINT
160 PRINT "IS THE NOSE OF THE PROJECTILE A CONE OR AN ";
170 PRINT "OGIVE (C OR O): ";
180 INPUT A$
190 IF A$<>"O" THEN 260
200 PRINT
210 PRINT
220 PRINT "LOADING PROGRAM FOR OGIVAL PROJECTILE"
230 FIND 2
240 OLD
250 GO TO 310
260 PRINT
270 PRINT
280 PRINT "LOADING PROGRAM FOR CONICAL PROJECTILE"
290 FIND 3
300 OLD
310 END
```

```
1 GO TO 100
4 GO TO 4360
8 GO TO 4600
12 GO TO 4950
16 GO TO 5470
20 GO TO 6040
24 GO TO 6590
28 GO TO 7380
32 GO TO 7940
36 GO TO 790
40 GO TO 2430
44 GO TO 3060
48 GO TO 8790
52 GO TO 3120
100 PAGE
110 INIT
120 DIM Y2(50),Y(20),Q1(13),Q(14,13),J1(17),J2(17)
130 PRINT "THIS PROGRAM WILL CALCULATE AND PLOT ESTIMATED AERODYNAMIC"
140 PRINT "CHARACTERISTICS OF SPIN STABILIZED, OGIVAL NOSED PROJECTI";
150 PRINT "LES "
160 PRINT "FOR 2<M<5."
170 PRINT
180 PRINT "INPUT ALL VALUES IN CALIBERS UNLESS OTHERWISE NOTED"
190 PRINT
200 PRINT "INPUT OGIVE LENGTH: ";
210 INPUT B4
220 PRINT "INPUT OGIVE RADIUS: ";
230 INPUT B5
240 PRINT "INPUT CYLINDRICAL BODY LENGTH: ";
250 INPUT D
260 PRINT "INPUT BOATTAIL LENGTH: ";
270 INPUT B3
280 IF B3=0 THEN 320
290 PRINT "INPUT BOATTAIL ANGLE (DEGREES,MINUTES): ";
```

```
300 INPUT D2,D1
310 GO TO 340
320 D1=0
330 D2=0
340 PRINT "INPUT RADIUS OF CURVATURE OFFSET (MEASURED FROM NOSE): ";
350 INPUT B
360 Z0=B
370 B=B-(B4+D+B3)
380 PRINT "INPUT ROTATING BAND RADIUS (ZERO IF EQUALS RADIUS OF CYLIND";
390 PRINT "ER): ";
400 INPUT B6
410 IF B6<>0 THEN 450
420 D3=0
430 L7=0
440 GO TO 490
450 PRINT "INPUT WIDTH OF ROTATING BAND: ";
460 INPUT D3
470 PRI "INPUT DISTANCE TO ROTATING BAND CENTER (MEASURED FROM BASE): ";
480 INPUT L7
490 PRINT "INPUT LENGTH OF BOOM EXTENTION (ZERO IF NO BOOM): ";
500 INPUT L1
510 PRI "INPUT CENTER OF GRAVITY OF PROJECTILE (MEASURED FROM NOSE): ";
520 INPUT L6
530 PRINT
540 PRINT "ENTER 'Y' FOR GRAPH OF VELOCITY vs. RANGE: ";
550 INPUT C$
560 IF C$<>"Y" THEN 770
570 PRINT
580 PRINT "INPUT THESE RANGE VALUES"
590 PRINT
600 PRINT "INPUT AXIAL MOMENT OF INERTIA (CAL↑5): ";
610 INPUT I1
620 PRINT "INPUT TRANSVERSE MOMENT OF INERTIA (CAL↑5): ";
630 INPUT I2
640 PRINT "INPUT WEIGHT OF PROJECTILE (CAL↑3): ";
```

```
650 INPUT M5
660 PRINT "INPUT TWIST OF PROJECTILE (NO. OF CALIBERS/REV): ";
670 INPUT N
680 PRINT "INPUT DIAMETER OF PROJECTILE (MM): ";
690 INPUT D6
700 PRINT "INPUT THE DENSITY OF THE AIR (.001225 (g/cc) IS STANDARD): ";
710 INPUT R0
720 PRINT "INPUT MUZZLE MACH NUMBER: ";
730 INPUT M0
740 PRINT "INPUT MAXIMUM RANGE OF PROJECTILE (<=4000 METERS): ";
750 INPUT S3
760 PRINT
770 PRINT "INPUT PLOTTING DEVISE NUMBER(1=PEN PLOTTER,32=SCREEN): ";
780 INPUT A
790 PAGE
800 SET DEGREES
810 VIEWPORT 0,130,0,100
820 WINDOW -1,10,-6,4
830 MOVE @A:-1,0
840 DRAW @A:B4+D+B3+1,0
850 M=2
860 D4=D1/60
870 D5=D4+D2
880 IF D5<>0 THEN 960
890 HOME @A:
900 PRINT @A:"JJ"
910 PRINT @A: USING 950:"OGIVE CYLINDER PROJECTILE DESIGN"
920 MOVE @A:D+B4,0.5
930 DRAW @A:D+B4,-0.5
940 HOME @A:
950 IMAGE10X,32A
960 MOVE @A:D+B4,-0.5
970 DRAW @A:B4,-0.5
980 MOVE @A:B4,0.5
990 DRAW @A:B4+D,0.5
```

```
1000 MOVE @A:B4,0.5
1010 X=B4
1020 X1=B+D+B4+B3
1030 Y1=0.5-SQR(B5↑2-(D+B3+B)↑2)
1040 FOR R2=1 TO 50
1050 Y2(R2)=SQR(B5↑2-(X-(B+D+B4+B3))↑2)+Y1
1060 DRAW @A:X,Y2(R2)
1070 X=X-0.1
1080 IF X<0 THEN 1100
1090 NEXT R2
1100 MOVE @A:B4,-0.5
1110 X=B4
1120 FOR R1=1 TO 50
1130 Y2(R1)=-(SQR(B5↑2-(X-(B+D+B4+B3))↑2)+Y1)
1140 DRAW @A:X,Y2(R1)
1150 X=X-0.1
1160 IF X<0 THEN 1180
1170 NEXT R1
1180 X4=SIN(D5)*B3/SIN(90-D5)
1190 L4=0.5-X4
1200 MOVE @A:L6,0
1210 RMOVE @A:-0.04,-0.11
1220 PRINT @A:"+"
1230 MOVE @A:L6,0
1240 RMOVE @A:-0.04,-0.11
1250 PRINT @A:"O"
1260 IF B3=0 THEN 1310
1270 MOVE @A:D+B4,0.5
1280 DRAW @A:D+B4+B3,L4
1290 DRAW @A:D+B4+B3,-L4
1300 DRAW @A:D+B4,-0.5
1310 IF L1=0 THEN 1360
1320 MOVE @A:D+B4+B3,0.05
1330 DRAW @A:D+B3+B4+L1,0.05
1340 DRAW @A:D+B3+B4+L1,-0.05
```

```
1350 DRAW @A:D+B3+B4,-0.05
1360 IF B6=0 THEN 1420
1370 MOVE @A:D+B3+B4-L7,B6
1380 DRAW @A:D+B3+B4-L7-D3,B6
1390 DRAW @A:D+B4+B3-L7-D3,-B6
1400 DRAW @A:D+B4+B3-L7,-B6
1410 DRAW @A:D+B3+B4-L7,B6
1420 MOVE @A:0,-0.1
1430 DRAW @A:0,-2.5
1440 MOVE @A:B4,-0.6
1450 DRAW @A:B4,-1.2
1460 MOVE @A:0,-0.8
1470 DRAW @A:B4/3,-0.8
1480 RMOVE @A:0,-0.1
1490 PRINT @A: USING 1520:B4
1500 RMOVE @A:1,0.1
1510 DRAW @A:B4,-0.8
1520 IMAGE 2D.3D
1530 MOVE @A:L6,-0.6
1540 DRAW @A:L6,-1.8
1550 MOVE @A:0,-1.45
1560 DRAW @A:L6/2-0.5,-1.45
1570 MOVE @A:L6/2-0.5,-1.55
1580 PRINT @A: USING 1590:L6
1590 IMAGE 2D.3D
1600 MOVE @A:L6/2+0.5,-1.45
1610 DRAW @A:L6,-1.45
1620 IF D=0 THEN 1720
1630 MOVE @A:B4+D+B3,-0.6
1640 DRAW @A:B4+D+B3,-2.5
1650 MOVE @A:0,-2.1
1660 DRAW @A:(B4+D+B3)/2-0.5,-2.1
1670 MOVE @A:(B4+D+B3)/2-0.5,-2.2
1680 PRINT @A: USING 1690:B4+D+B3
1690 IMAGE 2D.3D
```

```
1700 MOVE @A:(B4+D+B3)/2+0.5,-2.1
1710 DRAW @A:B4+D+B3,-2.1
1720 IF B3=0 THEN 1990
1730 MOVE @A:D+B4,-0.6
1740 DRAW @A:D+B4,-1.8
1750 MOVE @A:D+B4,-1.45
1760 DRAW @A:D+B4+B3+0.2,-1.45
1770 RMOVE @A:0.1,-0.1
1780 PRINT @A: USING 1790:B3
1790 IMAGE1D.2D
1800 MOVE @A:D+B4+0.3,0.5
1810 DRAW @A:D+B4+B3+0.5,0.5
1820 E1=0.1*SIN(D5)/SIN(90-D5)
1830 MOVE @A:D+B4+B3+0.1,L4-E1
1840 E=(B3+0.5)*SIN(D5)/SIN(90-D5)
1850 DRAW @A:D+B4+B3+0.5,0.5-E
1860 MOVE @A:D+B4+B3+0.4,0.5
1870 DRAW @A:D+B4+B3+0.4,0.7
1880 F1=L4+X4/B3*(D+B4+B3)
1890 F2=-(X4/B3)*(D+B4+B3+0.4)+F1
1900 F3=F2-B3/X4*(D+B4+B3+0.4)
1910 F4=B3/X4*(D+B4+B3+0.38)+F3
1920 MOVE @A:D+B4+B3+0.4,F2
1930 DRAW @A:D+B4+B3+0.38,F4
1940 MOVE @A:D+B4+B3+0.4,0.7
1950 DRAW @A:D+B4+B3+0.6,0.7
1960 RMOVE @A:0.1,-0.1
1970 PRINT @A: USING 1980:D5," DEG"
1980 IMAGE2D.2D,4A
1990 IF L1=0 THEN 2070
2000 MOVE @A:D+B4+B3,-0.7
2010 DRAW @A:D+B4+B3+L1+0.1,-0.7
2020 MOVE @A:D+B4+B3+L1,-0.6
2030 DRAW @A:D+B4+B3+L1,-0.8
2040 MOVE @A:D+B4+B3+L1+0.2,-0.8
```

```
2050 PRINT @A: USING 2060:L1
2060 IMAGE 2D.2D
2070 MOVE @A:0,0.1
2080 DRAW @A:0,2
2090 IF B<=0 THEN 2120
2100 MOVE @A:B4+D+B3+0.1,0.5
2110 DRAW @A:B4+D+B3+B+0.2,0.5
2120 MOVE @A:B4+B3+D+B,0.5
2130 DRAW @A:B4+B3+D+B,0.8
2140 DRAW @A:B4+B3+D+B+0.1,0.83
2150 DRAW @A:B4+B3+D+B-0.1,0.88
2160 DRAW @A:B4+B3+B+D,0.93
2170 DRAW @A:B4+B3+D+B,2
2180 MOVE @A:B4+B3+D+B,1.2
2190 DRAW @A:5*B4/6,1.2
2200 DRAW @A:B4-1,Y2(10)
2210 MOVE @A:B4-1.5,1.2
2220 RMOVE @A:0,0.05
2230 PRINT @A: USING 2240:B5," R"
2240 IMAGE 2D.2D,7A
2250 MOVE @A:B4+B3+B+D-0.05,1.25
2260 DRAW @A:B4+B3+D+B+0.05,1.15
2270 MOVE @A:B4+B3+D+B+0.05,1.25
2280 DRAW @A:B4+B3+B+D-0.05,1.15
2290 PRINT @A: USING 2300:"(",X1,",",ABS(Y1),")"
2300 IMAGE 1X,1A,2D.2D,1A,2D.2D,1A
2310 IF B3=0 THEN 2350
2320 HOME @A:
2330 PRI @A: USI 2340:"SECANT OGIVE CYLINDER BOATTAIL PROJECTILE DESIGN"
2340 IMAGE 5X,40A
2350 HOME @A:
2360 PRINT @A:"JJJJJJJJJJJJJJJJJ"
2370 PRINT @A:"JJJJJJJJJ"
2380 PRINT "G"
2390 PRI "IF YOU WANT INITIAL DATA PRINTED OUT OR CHANGED ENTER `Y': ";
```

```
2400 INPUT B$
2410 IF B$="Y" THEN 2430
2420 GO TO 2970
2430 PAGE
2440 PRINT "ALL VALUES ARE IN CALIBERS UNLESS OTHERWISE NOTED"
2450 PRINT
2460 PRINT "B4    OGIVE LENGTH: ";
2470 PRINT USING 2670:B4
2480 PRINT "B5    OGIVE RADIUS: ";
2490 PRINT USING 2670:B5
2500 PRINT "D     CYLINDRICAL BODY LENGTH: ";
2510 PRINT USING 2670:D
2520 PRINT "L6    CENTER OF GRAVITY OF PROJECTILE (NOSE): ";
2530 PRINT USING 2670:L6
2540 PRINT "B3    BOATTAIL LENGTH: ";
2550 PRINT USING 2670:B3
2560 D5=D2+D1/60
2570 PRINT "D2,D1 BOATTAIL ANGLE (DEGREES,MINUTES): ";
2580 PRINT USING 2670:D5
2590 PRINT "B6    ROTATING BAND RADIUS: ";
2600 PRINT USING 2670:B6
2610 PRINT "D3    ROTATING BAND WIDTH: ";
2620 PRINT USING 2670:D3
2630 PRINT "L7    DISTANCE TO ROTATING BAND FROM BASE: ";
2640 PRINT USING 2670:L7
2650 PRINT "L1    LENGTH OF BOOM EXTENTION: ";
2660 PRINT USING 2670:L1
2670 IMAGE 2D.2D
2680 IF C$<>"Y" THEN 2900
2690 PRINT "I1    AXIAL MOMENT OF INERTIA (CAL↑5): ";
2700 PRINT USING 2710:I1
2710 IMAGE 4D.2D
2720 PRINT "I2    TRANSVERSE MOMENT OF INERTIA (CAL↑5): ";
2730 PRINT USING 2710:I2
2740 PRINT "M5    WEIGHT OF PROJECTILE (CAL↑3): ";
```

```
2750 PRINT USING 2710:M5
2760 PRINT "N     TWIST OF PROJECTILE (NO. OF CAL/REV): ";
2770 PRINT USING 2780:N
2780 IMAGE 2D.2D
2790 PRINT "D6    DIAMETER OF PROJECTILE (MM): ";
2800 PRINT USING 2810:D6
2810 IMAGE 2D.3D
2820 PRINT "R0    DENSITY OF AIR (g/cc): ";
2830 PRINT USING 2840:R0
2840 IMAGE 1D.6D
2850 PRINT "M0    MUZZLE MACH NUMBER: ";
2860 PRINT USING 2780:M0
2870 PRINT "S3    MAXIMUM RANGE OF PROJECTILE (METERS,<=4000): ";
2880 PRINT USING 2890:S3
2890 IMAGE 4D
2900 PRINT "A     PLOTTING DEVISE (1=PEN PLOTTER, 32=SCREEN):";
2910 PRINT USING 2890:A
2920 PRINT "JJ"
2930 PRINT "G"
2940 PRINT "DO YOU WISH TO CHANGE ANY DATA (Y OR N): ";
2950 INPUT D$
2960 IF D$="Y" THEN 3010
2970 PRINT "ENTER 'Y' FOR MENU AND CALCULATIONS: ";
2980 INPUT B$
2990 IF B$="Y" THEN 3070
3000 GO TO 3060
3010 PRINT
3020 PRI "TO CHANGE DATA, TAKE VARIABLE NAME IN LEFT HAND COLUMN AND E";
3030 PRINT "QUATE IT TO "
3040 PRINT "NEW PARAMETER (i.e. B4=1).  TO VIEW NEW PARAMETERS PRESS U";
3050 PRINT "DK#10.  TO    CALCULATE VALUES PRESS UDK#11."
3060 END
3070 PAGE
3080 PRINT "PLEASE WAIT, CALCULATIONS IN PROGRESS"
3090 GOSUB 3380
```

```
3100 REM
3110 REM THIS IS THE MENU
3120 REM
3130 PAGE
3140 PRINT "                                   USER DEFINABLE KEY DEFINITIONS"
3150 PRINT "JJJ"
3160 REM
3170 REM THIS IS THE MENU
3180 REM
3190 PRINT "1......NOMENCLATURE"
3200 PRINT "2......TABLE OF AERODYNAMIC COEFFICIENTS"
3210 PRINT "3......CDT vs. MACH NUMBER PLOT"
3220 PRINT "4......CNA vs. MACH NUMBER PLOT"
3230 PRINT "5......CMA vs. MACH NUMBER PLOT"
3240 PRINT "6......Cmq+Cm'α vs. MACH NUMBER PLOT"
3250 PRINT "7......CMPA vs. MACH NUMBER PLOT"
3260 PRINT "8......VELOCITY vs. RANGE PLOT"
3270 PRINT "9......SPIN STABILIZED PROJECTILE DESIGN"
3280 PRINT "10.....REVIEW AND CHANGE ORIGINAL DATA"
3290 PRINT "11.....CALCULATIONS"
3300 PRINT "12.....SET PARAMETERS FOR DIFFERENT PROJECTILE"
3310 PRINT "13.....RETURN TO MENU"
3320 PRINT
3330 PRINT
3340 PRINT
3350 PRINT "PLEASE PRESS USER DEFINABLE KEY TO CONTINUE"
3360 PRINT "G"
3370 END
3380 REM
3390 REM                    CALCULATIONS
3400 REM
3410 REM
3420 REM
3430 REM
3440 N=2
```

```
3450 L3=B3+D
3460 REM L3 IS THE AFTER BODY LENGTH
3470 L4=0.5-X4
3480 REM L4 IS THE RADIUS OF THE BASE
3490 FOR T=1 TO 13
3500 Q1(T)=M
3510 C1=0.4/(B4↑0.28*M↑0.53)*0.78
3520 C2=(0.15-0.03*M+0.01/M+1.0E-4*M↑3.6)*(L3/3+B4/4)
3530 C2=0.25*C2/M*30↑(4.6/B5)
3540 C3=2*(0.265-0.04*M)*L4↑2
3550 IF B6=0 THEN 3580
3560 C4=0.015
3570 GO TO 3590
3580 C4=0
3590 C=C1+C2+C3+C4
3600 N1=B4*(0.21-0.01*M)+L3/1.75*(3-0.4*M)
3610 N1=0.9594*EXP(0.084*M)/B4↑0.217/B5↑0.783/M↑0.518
3620 N1=N1*49.296*M↑0.594-N1*LOG(32.5/B5)*LOG(2.61/M)
3630 N1=((0.7456-0.2774/EXP(0.0558*M))*LOG(B5/32.5)+1)*N1
3640 H=N1
3650 REM  H IS CNASQ
3660 IF B3=0 THEN 3700
3670 N1=0.15-0.046*SQR(M)+7*SQR(M)/B5*LOG(7/B5)+N1
3680 H1=N1
3690 GO TO 3720
3700 H1=0
3710 REM H1=CNABT
3720 IF L1=0 THEN 3760
3730 N1=(1.24-0.071*M)*L1*N1
3740 H2=N1
3750 GO TO 3790
3760 REM H2 IS CNA(W/BOOM)
3770 H2=0
3780 REM N1 IS CNA  TOTAL
3790 F=L7-B3/2
```

```
3810 W=F*M/B5
3820 N9=1.649+0.213*LOG(M)+0.431*LOG(B5/32.5)
3830 N9=N9-0.05*LOG(B5/32.5)*LOG(M)-0.026*LOG(M)↑2*LOG(B5/32.5)
3840 N9=N9+0.08*TAN(D5)+M↑0.75/4.5+L1*(0.354-0.234*M+0.0027*M*M)
3850 IF D5=0 THEN 3880
3860 GO TO 3870
3880 N9=1.25*N9
3960 REM N0 IS CMA
3970 M1=(0.166*M-0.966)*B4-(0.237*M+1.91)*L3-0.123*B5
3980 REM M1 IS CM0+CM'A
3990 M2=(0.107-0.01*M)*B4+(0.0375-0.002*M)*L3+0.02*B3
4000 REM M2 IS CMPA
4010 M3=N9
4011 N9=L6-N9
4012 REM N9 IS NOW THE STATIC MARGIN
4020 REM M3 IS THE CP OF THE NORMAL FORCE FOR AN OGIVE
4030 N0=N9*N1
4032 J=N0
4040 Q(1,T)=C1
4050 Q(2,T)=C2
4060 Q(3,T)=C3
4070 Q(4,T)=C4
4080 Q(5,T)=C
4090 Q(6,T)=H
4100 Q(7,T)=H1
4110 Q(8,T)=H2
4120 Q(9,T)=N1
4130 Q(10,T)=M1
4140 Q(11,T)=M2
```

```
4150 Q(12,T)=M3
4160 Q(13,T)=N0
4170 M=M+0.25
4180 NEXT T
4190 IF C$<>"Y" THEN 4400
4200 A1=PI/4
4210 K=Q(5,9)-Q(5,5)
4220 B0=-(K*3)+Q(5,5)
4230 Q2=R0*A1*B0/(2*M5)
4240 R4=(K*M0+B0)/M0
4250 S=I1↑2*2*(2*PI/N)↑2/(PI*R0*I2*J)
4260 S1=2*PI/((I1/I2)↑2*(2*PI/N)↑2-PI*R0/(2*I2)*J)↑0.5
4270 S2=0
4280 FOR T=1 TO 17
4290 V=B0/(R4*EXP(Q2*S2/(D6/1000))-K)*340.29
4300 J1(T)=V
4310 S2=S2+250
4320 IF S2>S3 THEN 4340
4330 NEXT T
4340 K1=S3/250+1
4350 FOR T=2 TO K1
4360 J2(T)=(J1(1)-J1(T))/(T-1)/250*1000
4370 IF J1(T)=V THEN 4390
4380 NEXT T
4390 J2(1)=J2(2)
4400 RETURN
4410 REM
4420 REM NOMENCLATURE
4430 REM
4440 PAGE
4450 PRINT
4460 PRINT "                              NOMENCLATURE"
4470 PRINT "JJJ"
4480 PRINT "CDWB      Coefficient of wave drag for the projectile body"
4490 PRINT "CDVB      Viscous drag coefficient for the projectile body"
```

```
4500 PRINT "CDBB      Base drag coefficient for the projectile body"
4510 PRI "CDRB      Rotating band drag coefficient for the projectile";
4520 PRINT " body"
4530 PRINT "CDT       Total drag coefficient for the projectile body"
4540 PRI "CNASQ     Normal force slope coefficient for a square based";
4550 PRINT " projectile"
4560 PRI "CNABT     Normal force coefficient for boattailed projectile"
4570 PRI "CNABE     Normal force slope coefficient with boom extension"
4580 PRINT "CNAT      Total normal force slope coefficient"
4590 PRINT "Cmq+Cm'a  Damping moment slope coefficient"
4600 PRINT "CMPA      Magnus moment slope coefficient"
4610 PRINT "CP        Center of pressure of the normal force"
4620 PRINT "CMA       Static moment slope coefficient"
4630 PRINT "G"
4640 END
4650 REM THIS IS THE TABLE OF CALCULATIONS
4660 REM
4670 PAGE
4680 PRINT "   AERODYNAMIC COEFFICIENTS FOR SPIN STABILIZED";
4690 PRINT " PROJECTILES"
4700 PRINT
4710 PRINT USING 4720:"MACH NUMBER"
4720 IMAGE 30X,11A
4730 PRINT
4740 PRINT USING 4750:"2.0","2.5","3.0","3.5","4.0","4.5","5.0"
4750 IMAGE   12X,3A,6X,3A,7X,3A,7X,4(3A,6X)
4760 PRINT "CDWB"
4770 PRINT "CDVB"
4780 PRINT "CDBB"
4790 PRINT "CDRB"
4800 PRINT "CDT"
4810 PRINT "CNASQ"
4820 PRINT "CNABT"
4830 PRINT "CNABE"
4840 PRINT "CNAT"
```

```
4850 PRINT "Cmq+Cm`a"
4860 PRINT "CMPA"
4870 PRINT "CP(NOSE)"
4880 PRINT "CMA"
4890 HOME
4900 PRINT "JJJJJ"
4910 FOR T=1 TO 13
4920 PRINT USING 4930:Q(T,1),Q(T,3),Q(T,5),Q(T,7),Q(T,9),Q(T,11),Q(T,13)
4930 IMAGE 8X,2(4D.3D,1X),2(1X,4D.3D,1X),2(4D.3D,1X),4D.3D
4940 NEXT T
4950 PRINT "G"
4960 END
4970 REM
4980 REM THIS IS THE GRAPH OF CDT vs. MACH NUMBER
4990 REM
5000 PAGE
5010 VIEWPORT 20,125,12,90
5020 WINDOW 1.75,5,0,0.5
5030 AXIS @A:0.25,0.025
5040 MOVE @A:2,0
5050 RMOVE @A:-0.07,-0.025
5060 PRINT @A:"2.0"
5070 FOR R=3 TO 5
5080 RMOVE @A:1,0
5090 PRINT @A: USING 5100:R
5100 IMAGE 1D.1D
5110 NEXT R
5120 MOVE @A:1.75,0.1
5130 RMOVE @A:-0.2,-0.007
5140 PRINT @A:"0.1"
5150 FOR R=0.2 TO 0.5 STEP 0.1
5160 RMOVE @A:0,0.1
5170 PRINT @A: USING 5180:R
5180 IMAGE 1D.1D
5190 NEXT R
```

```
5200 PRINT @A:"JJJJJJJJJJJ"
5210 PRINT @A: USING 5220:"CDT"
5220 IMAGE 5X,3A
5230 PRINT @A:"JJJJJJJJJJJJJJJ"
5240 PRINT @A: USING 5250:"MACH No."
5250 IMAGE 38X,8A
5260 MOVE @A:2,0
5270 RMOVE @A:-0.016,0
5280 PRINT @A:"|"
5290 FOR R=3 TO 5
5300 RMOVE @A:1,0
5310 PRINT @A:"|"
5320 NEXT R
5330 MOVE @A:1.75,0.1
5340 IF A<>1 THEN 5370
5350 RMOVE @A:0.04,-0.0053
5360 GO TO 5380
5370 RMOVE @A:0.04,-0.0073
5380 PRINT @A:"-"
5390 FOR R=0.2 TO 0.5 STEP 0.1
5400 RMOVE @A:0,0.1
5410 PRINT @A:"-"
5420 NEXT R
5430 HOME @A:
5440 PRINT @A: USING 5450:"CDT vs. MACH No."
5450 IMAGE 35X,16A
5460 MOVE @A:Q1(1),Q(5,1)
5470 FOR R=2 TO 13
5480 DRAW @A:Q1(R),Q(5,R)
5490 NEXT R
5500 PRINT "G"
5510 END
5520 REM
5530 REM THIS IS THE GRAPH OF CNA vs. MACH No.
5540 REM
```

```
5550 PAGE
5560 VIEWPORT 20,125,12,90
5570 WINDOW 1.75,5,0.5,6
5580 AXIS @A:0.25,0.1
5590 MOVE @A:2,0.5
5600 RMOVE @A:-0.07,-0.23
5610 PRINT @A:"2.0"
5620 FOR R=3 TO 5
5630 RMOVE @A:1,0
5640 PRINT @A: USING 5650:R
5650 IMAGE 1D.1D
5660 NEXT R
5670 MOVE @A:1.75,1
5680 RMOVE @A:-0.2,-0.045
5690 PRINT @A:"1.0"
5700 FOR R=2 TO 6
5710 RMOVE @A:0,1
5720 PRINT @A: USING 5730:R
5730 IMAGE 1D.1D
5740 NEXT R
5750 MOVE @A:2,0.5
5760 RMOVE @A:-0.017,0
5770 PRINT @A:"|"
5780 FOR R=3 TO 5
5790 RMOVE @A:1,0
5800 PRINT @A:"|"
5810 NEXT R
5820 MOVE @A:1.75,1
5830 IF A<>1 THEN 5860
5840 RMOVE @A:0.027,-0.06
5850 GO TO 5870
5860 RMOVE @A:0.027,-0.08
5870 PRINT @A:"-"
5880 FOR R=1.5 TO 6 STEP 0.5
5890 RMOVE @A:0,0.5
```

```
5900 PRINT @A:"-"
5910 NEXT R
5920 HOME @A:
5930 PRINT @A: USING 5940:"CNAT vs. MACH No."
5940 IMAGE 35X,17A
5950 PRINT @A:"JJJJJJJJJJJJJJJJ"
5960 PRINT @A: USING 5970:"CNAT"
5970 IMAGE 4X,4A
5980 PRINT @A:"JJJJJJJJJJJJJJJ"
5990 PRINT @A: USING 6000:"MACH No."
6000 IMAGE 38X,8A
6010 MOVE @A:Q1(1),Q(9,1)
6020 FOR R=2 TO 13
6030 DRAW @A:Q1(R),Q(9,R)
6040 NEXT R
6050 HOME @A:
6060 PRINT "G"
6070 END
6080 REM
6090 REM THIS IS THE GRAPH OF CMA vs. MACH No.
6100 REM
6110 PAGE
6120 VIEWPORT 20,125,12,90
6130 WINDOW 1.75,5,0,6
6140 AXIS @A:0.25,0.25
6150 MOVE @A:2,0
6160 RMOVE @A:-0.062,-0.3
6170 PRINT @A:"2.0"
6180 FOR R=3 TO 5
6190 RMOVE @A:1,0
6200 PRINT @A: USING 6210:R
6210 IMAGE 1D.1D
6220 NEXT R
6230 MOVE @A:1.75,1
6240 RMOVE @A:-0.2,-0.08
```

```
6250 PRINT @A:"1.0"
6260 FOR R=2 TO 6
6270 RMOVE @A:0,1
6280 PRINT @A: USING 6290:R
6290 IMAGE 1D.1D
6300 NEXT R
6310 MOVE @A:2,0
6320 RMOVE @A:-0.018,0
6330 PRINT @A:"|"
6340 FOR R=3 TO 5
6350 RMOVE @A:1,0
6360 PRINT @A:"|"
6370 NEXT R
6380 MOVE @A:1.75,1
6390 IF A<>1 THEN 6420
6400 RMOVE @A:0.03,-0.065
6410 GO TO 6430
6420 RMOVE @A:0.03,-0.095
6430 PRINT @A:"-"
6440 FOR R=2 TO 6
6450 RMOVE @A:0,1
6460 PRINT @A:"-"
6470 NEXT R
6480 HOME @A:
6490 PRINT @A: USING 6500:"CMA vs. MACH No."
6500 IMAGE 35X,17A
6510 PRINT @A:"JJJJJJJJJJJJJ"
6520 PRINT @A: USING 6530:"CMA"
6530 IMAGE 5X,3A
6540 PRINT @A:"JJJJJJJJJJJJJJJJJ"
6550 PRINT @A: USING 6560:"MACH No."
6560 IMAGE 38X,8A
6570 MOVE @A:Q1(1),Q(13,1)
6580 FOR R=2 TO 13
6590 DRAW @A:Q1(R),Q(13,R)
```

```
6600 NEXT R
6610 HOME @A:
6620 PRINT "G"
6630 END
6640 REM
6650 REM THIS IS THE GRAPH OF CMQ+CMA vs. MACH No.
6660 REM
6670 PAGE
6680 VIEWPORT 20,125,12,90
6690 WINDOW 1.75,5,0,20
6700 AXIS @A:0.25,0.5
6710 MOVE @A:2,0
6720 RMOVE @A:-0.07,-0.85
6730 PRINT @A:"2.0"
6740 FOR R=3 TO 5
6750 RMOVE @A:1,0
6760 PRINT @A: USING 6770:R
6770 IMAGE 1D.1D
6780 NEXT R
6790 MOVE @A:1.75,2
6800 RMOVE @A:-0.2,-0.014
6810 PRINT @A:"2.0"
6820 FOR R=4 TO 9 STEP 2
6830 RMOVE @A:0,2
6840 PRINT @A: USING 6850:R
6850 IMAGE 1D.1D
6360 NEXT R
6870 MOVE @A:1.75,10
6880 RMOVE @A:-0.25,-0.014
6890 PRINT @A:"10.0"
6900 FOR R=12 TO 20 STEP 2
6910 RMOVE @A:0,2
6920 PRINT @A: USING 6930:R
6930 IMAGE 2D.1D
6940 NEXT R
```

```
6950 PRINT @A:"JJJJJJJJJJJ"
6960 PRINT @A: USING 6990:"Cmq"
6970 PRINT @A: USING 6990:" +"
6980 PRINT @A: USING 6990:"Cm'q"
6990 IMAGE 2X,4A
7000 PRINT @A:"JJJJJJJJJJJJJ"
7010 PRINT @A: USING 7020:"MACH No."
7020 IMAGE 38X,8A
7030 MOVE @A:2,0
7040 RMOVE @A:-0.016,0
7050 PRINT @A:"I"
7060 FOR R=3 TO 5
7070 RMOVE @A:1,0
7090 PRINT @A:"I"
7090 NEXT R
7100 MOVE @A:1.75,2
7110 IF A<>1 THEN 7140
7120 RMOVE @A:0.04,-0.2
7130 GO TO 7150
7140 RMOVE @A:0.04,-0.3
7150 PRINT @A:"-"
7160 FOR R=4 TO 20 STEP 2
7170 RMOVE @A:0,2
7180 PRINT @A:"-"
7190 NEXT R
7200 MOVE @A:1.75,2
7210 RMOVE @A:-0.25,-0.03
7220 PRINT @A:"-"
7230 FOR R=4 TO 9 STEP 2
7240 RMOVE @A:0,2
7250 PRINT @A:"-"
7260 NEXT R
7270 MOVE @A:1.75,10
7280 RMOVE @A:-0.3,-0.03
7290 PRINT @A:"-"
```

```
7300 FOR R=12 TO 20 STEP 2
7310 RMOVE @A:0,2
7320 PRINT @A:"-"
7330 NEXT R
7340 HOME @A:
7350 PRINT @A: USING 7360:"Cmq+Cm'a vs. MACH No."
7360 IMAGE 32X,21A
7370 MOVE @A:Q1(1),ABS(Q(10,1))
7380 FOR R=2 TO 13
7390 DRAW @A:Q1(R),ABS(Q(10,R))
7400 NEXT R
7410 PRINT @A:"G"
7420 END
7430 REM
7440 REM THIS IS THE GRAPH OF CMPA vs. MACH No.
7450 REM
7460 PAGE
7470 VIEWPORT 20,125,12,90
7480 WINDOW 1.75,5,0,1
7490 AXIS @A:0.25,0.025
7500 MOVE @A:2,0
7510 RMOVE @A:-0.07,-0.05
7520 PRINT @A:"2.0"
7530 FOR R=3 TO 5
7540 RMOVE @A:1,0
7550 PRINT @A: USING 7560:R
7560 IMAGE1D.1D
7570 NEXT R
7580 MOVE @A:1.75,0.1
7590 RMOVE @A:-0.2,-0.014
7600 PRINT @A:"0.1"
7610 FOR R=0.2 TO 1 STEP 0.1
7620 RMOVE @A:0,0.1
7630 PRINT @A: USING 7640:R
7640 IMAGE 1D.1D
```

```
7650 NEXT R
7660 PRINT @A:"JJJJJJJJJJJ"
7670 PRINT @A: USING 7680:"CMPA"
7680 IMAGE3X,4A
7690 PRINT @A:"JJJJJJJJJJJJJJJ"
7700 PRINT @A: USING 7710:"MACH No."
7710 IMAGE 38X,8A
7720 MOVE @A:2,0
7730 RMOVE @A:-0.017,0
7740 PRINT @A:"I"
7750 FOR R=3 TO 5
7760 RMOVE @A:1,0
7770 PRINT @A:"I"
7780 NEXT R
7790 MOVE @A:1.75,0.1
7800 IF A<>1 THEN 7830
7810 RMOVE @A:0.04,-0.01
7820 GO TO 7840
7830 RMOVE @A:0.04,-0.0146
7840 PRINT @A:"-"
7850 FOR R=0.2 TO 1 STEP 0.1
7860 RMOVE @A:0,0.1
7870 PRINT @A:"-"
7880 NEXT R
7890 HOME @A:
7900 PRINT @A: USING 7910:"CMPA vs. MACH No."
7910 IMAGE 32X,17A
7920 MOVE @A:Q1(1),Q(11,1)
7930 FOR R=2 TO 13
7940 DRAW @A:Q1(R),Q(11,R)
7950 NEXT R
7960 PRINT "G"
7970 END
7980 REM
7990 REM THIS IS THE GRAPH OF VELOCITY vs. RANGE
```

```
8000 REM
8010 PAGE
8020 IF C$<>"Y" THEN 8820
8030 VIEWPORT 20,125,40,90
8040 WINDOW 0,4,0,2000
8050 AXIS @A:0.25,100
8060 MOVE @A:0.5,0
8070 RMOVE @A:-0.08,-135
8080 PRINT @A:"0.5"
8090 FOR R=1 TO 4 STEP 0.5
8100 RMOVE @A:0.5,0
8110 PRINT @A: USING 8120:R
8120 IMAGE 1D.1D
8130 NEXT R
8140 MOVE @A:0,500
8150 RMOVE @A:-0.31,-30
8160 PRINT @A:"500"
8170 FOR R=1000 TO 2000 STEP 500
8180 RMOVE @A:0,500
8190 PRINT @A: USING 8200:R
8200 IMAGE 4D
8210 NEXT R
8220 MOVE @A:0.5,0
8230 RMOVE @A:-0.0195,10
8240 PRINT @A:"|"
8250 FOR R=1 TO 4 STEP 0.5
8260 RMOVE @A:0.5,0
8270 PRINT @A:"|"
8280 NEXT R
8290 MOVE @A:0,500
8300 IF A<>1 THEN 8330
8310 RMOVE @A:0.05,-33
8320 GO TO 8340
8330 RMOVE @A:0.05,-50
8340 PRINT @A:"-"
```

```
8350 FOR R=1000 TO 2000 STEP 500
8360 RMOVE @A:0,500
8370 PRINT @A:"-"
8380 NEXT R
8390 HOME @A:
8400 PRINT @A: USING 8410:"VELOCITY vs. RANGE"
8410 IMAGE 32X,18A
8420 IF A<>1 THEN 8500
8430 MOVE @A:-0.5,700
8440 PRINT @1,25:90
8450 PRINT @A: USING 8460:"VELOCITY (M/S)"
8460 IMAGE 14A
8470 PRINT @1,7:
8480 PRINT @A:"JJJJJJJJ"
8490 GO TO 8560
8500 PRINT @A:"JJJJJJJJ"
8510 PRINT @A: USING 8520:"VEL"
8520 IMAGE 2X,11A
8530 PRINT @A: USING 8540:"(M/SEC)"
8540 IMAGE 8A
8550 PRINT @A:"JJJJJJJJJJ"
8560 PRINT @A: USING 8570:"RANGE(KM)"
8570 IMAGE 37X,9A
8580 HOME @A:
8590 PRINT @A:"J"
8600 PRINT @A: USING 8610:"GYROSCOPIC STABILITY FACTOR: ",S
8610 IMAGE 2X,29A,2D.3D
8620 HOME @A:
8630 PRINT @A:"J"
8640 PRINT @A: USING 8650:"INITIAL YAW CYCLE: ",S1," CAL"
8650 IMAGE 42X,19A,4D.2D,4A
8660 J3=0
8670 MOVE @A:0,J1(1)
8680 FOR R=1 TO 17
8690 DRAW @A:J3/1000,J1(R)
```

```
8700 IF J1(R)=0 THEN 8730
8710 J3=J3+250
8720 NEXT R
8730 MOVE @A:0,0
8740 PRINT @A:"JJJJ"
8750 FOR S2=0 TO S3/250+1 STEP 2
8760 PRINT @A: USING 8770:(S3-S2*250)/1000,J2(K1-S2)
8770 IMA 15X,"RANGE: ",1D.1D," KM",12X,"RETARDATION: ",3D.3D," (M/S)/KM"
8780 NEXT S2
8790 HOME
8800 PRINT "G"
8810 GO TO 8830
8820 PRINT "NO PARAMETERS WERE GIVEN FOR VELOCITY vs. RANGE PLOT"
8830 END
8840 PAGE
8850 PRINT "DO YOU WISH TO VIEW ANOTHER PROJECTILE (Y OR N): ";
8860 INPUT F$
8870 IF F$<>"Y" THEN 8960
8880 PRINT
8890 PRINT "WILL THIS NEW PROJECTILE HAVE AN OGIVAL NOSE (Y OR N): ";
8900 INPUT G$
8910 IF G$="Y" THEN 100
8920 PRINT
8930 PRINT "LOADING PROGRAM FOR CONICAL PROJECTILE"
8940 FIND 3
8950 OLD
8960 END
```

```
1 GO TO 100
4 GO TO 3950
8 GO TO 4190
12 GO TO 4520
16 GO TO 5040
20 GO TO 5610
24 GO TO 6160
28 GO TO 6960
32 GO TO 7510
36 GO TO 750
40 GO TO 2220
44 GO TO 2840
48 GO TO 8370
52 GO TO 2870
100 PAGE
110 INIT
120 DIM Y2(50),Y(20),Q1(13),Q(14,13),J1(17),J2(17)
130 PRINT "THIS PROGRAM WILL CALCULATE AND PLOT ESTIMATED AERODYNAMIC"
140 PRINT "CHARACTERISTICS OF SPIN STABILIZED, CONICAL NOSED"
150 PRINT "PROJECTILES FOR 2<M<5."
160 PRINT
170 PRINT "INPUT ALL VALUES IN CALIBERS UNLESS OTHERWISE NOTED"
180 PRINT
190 SET DEGREES
200 PRINT "INPUT CONICAL NOSE LENGTH: ";
210 INPUT B4
220 B1=(0.5↑2+B4↑2)↑0.5
230 B2=ASN(0.5/B1)*2
240 PRINT "INPUT CYLINDRICAL BODY LENGTH: ";
250 INPUT D
260 PRINT "INPUT BOATTAIL LENGTH: ";
270 INPUT B3
280 IF B3=0 THEN 320
290 PRINT "INPUT BOATTAIL ANGLE (DEGREES,MINUTES): ";
```

```
300 INPUT D2,D1
310 GO TO 340
320 D1=0
330 D2=0
340 PRINT "INPUT ROTATING BAND RADIUS (ZERO IF EQUALS RADIUS OF CYLIND";
350 PRINT "ER): ";
360 INPUT B6
370 IF B6<>0 THEN 410
380 D3=0
390 L7=0
400 GO TO 450
410 PRINT "INPUT WIDTH OF ROTATING BAND: ";
420 INPUT D3
430 PRI "INPUT DISTANCE TO ROTATING BAND CENTER (MEASURED FROM BASE): ";
440 INPUT L7
450 PRINT "INPUT LENGTH OF BOOM EXTENTION (ZERO IF NO BOOM): ";
460 INPUT L1
470 PRI "INPUT CENTER OF GRAVITY OF PROJECTILE (MEASURED FROM NOSE): ";
480 INPUT L6
490 PRINT
500 PRINT "ENTER 'Y' FOR GRAPH OF VELOCITY vs. RANGE: ";
510 INPUT C$
520 IF C$<>"Y" THEN 730
530 PRINT
540 PRINT "INPUT THESE RANGE VALUES"
550 PRINT
560 PRINT "INPUT AXIAL MOMENT OF INERTIA (CAL↑5): ";
570 INPUT I1
580 PRINT "INPUT TRANSVERSE MOMENT OF INERTIA (CAL↑5): ";
590 INPUT I2
600 PRINT "INPUT WEIGHT OF PROJECTILE (CAL↑3): ";
610 INPUT M5
620 PRINT "INPUT TWIST OF PROJECTILE (NO. OF CALIBERS/REV): ";
630 INPUT N
640 PRINT "INPUT DIAMETER OF PROJECTILE (MM): ";
```

```
650 INPUT D6
660 PRINT "INPUT THE DENSITY OF THE AIR (STANDARD IS .001225 (g/cc)): ";
670 INPUT R0
680 PRINT "INPUT MUZZLE MACH NUMBER: ";
690 INPUT M0
700 PRINT "INPUT MAXIMUM RANGE OF PROJECTILE (<=4000 METERS): ";
710 INPUT S3
720 PRINT
730 PRINT "INPUT PLOTTING DEVISE NUMBER(1=PEN PLOTTER,32=SCREEN): ";
740 INPUT A
750 PAGE
760 VIEWPORT 0,130,0,100
770 IF B4+D+B3+L1<10 THEN 800
780 WINDOW -2,B4+D+B3+L1+1,-(B4+D+B3+L1)*0.6,(B4+D+B3+L1)*0.4
790 GO TO 810
800 WINDOW -1,10,-6,4
810 MOVE @A:-1,0
820 DRAW @A:B4+D+B3+1,0
830 M=2
840 D4=D1/60
850 D5=D4+D2
860 A1=0.5
870 MOVE @A:0,0
880 DRAW @A:B4;A1
890 IF D=0 THEN 920
900 MOVE @A:B4,-A1
910 GO TO 930
920 DRAW @A:B4,-A1
930 DRAW @A:0,0
940 MOVE @A:B4,A1
950 DRAW @A:B4+D,A1
960 IF B3=0 THEN 990
970 MOVE @A:D+B4,-A1
980 GO TO 1000
990 DRAW @A:B4+D,-A1
```

```
1000 DRAW @A:B4,-A1
1010 HOME @A:
1020 PRINT @A:"JJ"
1030 IF D<>0 THEN 1070
1040 PRINT @A: USING 1050:"CONICAL NOSE OF PROJECTILE"
1050 IMAGE 15X,26A
1060 GO TO 1090
1070 PRINT @A: USING 1080:"CONE CYLINDER PROJECTILE DESIGN"
1080 IMAGE 15X,32A
1090 X4=SIN(D5)*B3/SIN(90-D5)
1100 L4=0.5-X4
1110 MOVE @A:L6,0
1120 RMOVE @A:-0.04,-0.11
1130 PRINT @A:"+"
1140 MOVE @A:L6,0
1150 RMOVE @A:-0.04,-0.11
1160 PRINT @A:"O"
1170 IF D5=0 THEN 1220
1180 MOVE @A:D+B4,0.5
1190 DRAW @A:D+B4+B3,L4
1200 DRAW @A:D+B4+B3,-L4
1210 DRAW @A:D+B4,-0.5
1220 IF L1=0 THEN 1270
1230 MOVE @A:D+B4+B3,0.05
1240 DRAW @A:D+B3+B4+L1,0.05
1250 DRAW @A:D+B3+B4+L1,-0.05
1260 DRAW @A:D+B3+B4,-0.05
1270 IF B6=0 THEN 1340
1280 MOVE @A:D+B3+B4-L7,B6
1290 DRAW @A:D+B3+B4-L7-D3/2,B6
1300 DRAW @A:D+B4+B3-L7-D3/2,-B6
1310 DRAW @A:D+B4+B3-L7+D3/2,-B6
1320 DRAW @A:D+B3+B4-L7+D3/2,B6
1330 DRAW @A:D+B3+B4-L7,B6
1340 MOVE @A:0,-0.1
```

```
1350 DRAW @A:0,-2.5
1360 MOVE @A:B4,-0.6
1370 DRAW @A:B4,-1.2
1380 MOVE @A:0,-0.8
1390 DRAW @A:B4/3,-0.8
1400 MOVE @A:2*B4/3,-0.8
1410 DRAW @A:B4,-0.8
1420 MOVE @A:B4/3,-0.8
1430 RMOVE @A:0,-0.1
1440 PRINT @A: USING 1450:B4
1450 IMAGE    2D.3D
1460 MOVE @A:L6,-0.6
1470 DRAW @A:L6,-1.8
1480 MOVE @A:0,-1.45
1490 DRAW @A:L6/2-0.5,-1.45
1500 MOVE @A:L6/2-0.5,-1.55
1510 PRINT @A: USING 1520:L6
1520 IMAGE 2D.3D
1530 MOVE @A:L6/2+0.5,-1.45
1540 DRAW @A:L6,-1.45
1550 IF D=0 THEN 1650
1560 MOVE @A:B4+D+B3,-0.6
1570 DRAW @A:B4+D+B3,-2.5
1580 MOVE @A:0,-2.1
1590 DRAW @A:(B4+D+B3)/2-0.5,-2.1
1600 MOVE @A:(B4+D+B3)/2-0.5,-2.2
1610 PRINT @A: USING 1620:B4+D+B3
1620 IMAGE 2D.3D
1630 MOVE @A:(B4+D+B3)/2+0.5,-2.1
1640 DRAW @A:B4+D+B3,-2.1
1650 MOVE @A:B4/3,0
1660 DRAW @A:B4/3,-0.1
1670 A0=A1/B4*B4/3
1680 MOVE @A:B4/3,A0
1690 Z=A0+B4↑2/(A1*3)
```

```
1700 DRAW @A:B4/3-0.05,-(B4/A1)*(B4/3-0.05)+Z
1710 Z1=-(B4/A1)*(B4/3-0.05)+Z-(B4/3-0.05)*A1/B4
1720 DRAW @A:B4/3+0.2,A1/B4*(B4/3+0.2)+Z1
1730 RMOVE @A:0.05,-0.05
1740 PRINT @A: USING 1750:B2/2;" DEG"
1750 IMAGE 2D.2D,4A
1760 IF B3=0 THEN 2030
1770 MOVE @A:D+B4,-0.6
1780 DRAW @A:D+B4,-1.8
1790 MOVE @A:D+B4,-1.45
1800 DRAW @A:D+B4+B3+0.2,-1.45
1810 RMOVE @A:0.1,-0.1
1820 PRINT @A: USING 1830:B3
1830 IMAGE1D.2D
1840 MOVE @A:D+B4+0.3,0.5
1850 DRAW @A:D+B4+B3+0.5,0.5
1860 E1=0.1*SIN(D5)/SIN(90-D5)
1870 MOVE @A:D+B4+B3+0.1,L4-E1
1880 E=(B3+0.5)*SIN(D5)/SIN(90-D5)
1890 DRAW @A:D+B4+B3+0.5,0.5-E
1900 MOVE @A:D+B4+B3+0.4,0.5
1910 DRAW @A:D+B4+B3+0.4,0.7
1920 F1=L4+X4/B3*(D+B4+B3)
1930 F2=-(X4/B3)*(D+B4+B3+0.4)+F1
1940 F3=F2-B3/X4*(D+B4+B3+0.4)
1950 F4=B3/X4*(D+B4+B3+0.38)+F3
1960 MOVE @A:D+B4+B3+0.4,F2
1970 DRAW @A:D+B4+B3+0.38,F4
1980 MOVE @A:D+B4+B3+0.4,0.7
1990 DRAW @A:D+B4+B3+0.6,0.7
2000 RMOVE @A:0.1,-0.1
2010 PRINT @A: USING 2020:D5," DEG"
2020 IMAGE2D.2D,4A
2030 IF L1=0 THEN 2130
2040 MOVE @A:D+B4+B3,-0.7
```

```
2050 DRAW @A:D+B4+B3+L1+0.1,-0.7
2060 MOVE @A:D+B4+B3+L1,-0.7
2070 DRAW @A:D+B4+B3+L1,-0.8
2080 DRAW @A:D+B4+B3+L1,-0.6
2090 MOVE @A:D+B4+B3+L1+0.2,-0.8
2100 PRINT @A: USING 2110:L1
2110 IMAGE 2D.2D
2120 IMAGE 2D.2D
2130 MOVE @A:0,0.1
2140 DRAW @A:0,2
2150 IF B3=0 THEN 2160
2160 PRINT @A:"JJJJJJJJJJJJJJJJJJJJ"
2170 PRINT "G"
2180 PRI "IF YOU WANT INITIAL DATA PRINTED OUT OR CHANGED ENTER `Y': ";
2190 INPUT B$
2200 IF B$="Y" THEN 2220
2210 GO TO 2740
2220 PAGE
2230 PRINT "ALL VALUES ARE IN CALIBERS UNLESS OTHERWISE NOTED"
2240 PRINT
2250 PRINT "B4  CONICAL NOSE LENGTH: ";
2260 PRINT USING 2270:B4
2270 IMAGE 2D.2D
2280 PRINT "D   CYLINDRICAL BODY LENGTH: ";
2290 PRINT USING 2270:D
2300 PRINT "L6  CENTER OF GRAVITY OF PROJECTILE (MEASURED FROM NOSE): ";
2310 PRINT USING 2270:L6
2320 PRINT "B3  BOATTAIL LENGTH: ";
2330 PRINT USING 2270:B3
2340 PRINT "D5  BOATTAIL ANGLE (DEGREES): ";
2350 PRINT USING 2270:D5
2360 PRINT "B6  ROTATING BAND RADIUS: ";
2370 PRINT USING 2270:B6
2380 PRINT "D3  ROTATING BAND WIDTH: ";
2390 PRINT USING 2270:D3
```

```
2400 PRINT "L7  DISTANCE TO ROTATING BAND CENTER FROM BASE: ";
2410 PRINT USING 2270:L7
2420 PRINT "L1  LENGTH OF BOOM EXTENTION: ";
2430 PRINT USING 2270:L1
2440 IMAGE 2D.2D
2450 IF C$<>"Y" THEN 2670
2460 PRINT "I1  AXIAL MOMENT OF INERTIA (CAL↑5): ";
2470 PRINT USING 2480:I1
2480 IMAGE 4D.2D
2490 PRINT "I2  TRANSVERSE MOMENT OF INERTIA (CAL↑5): ";
2500 PRINT USING 2480:I2
2510 PRINT "M5  WEIGHT OF PROJECTILE (CAL↑3): ";
2520 PRINT USING 2480:M5
2530 PRINT "N   TWIST OF PROJECTILE (NO. OF CAL/REV): ";
2540 PRINT USING 2550:N
2550 IMAGE 2D.2D
2560 PRINT "D5  DIAMETER OF PROJECTILE (MM): ";
2570 PRINT USING 2580:D5
2580 IMAGE 2D.3D
2590 PRINT "R0  DENSITY OF AIR (g/cc): ";
2600 PRINT USING 2610:R0
2610 IMAGE2D.6D
2620 PRINT "M0  MUZZLE MACH NUMBER: ";
2630 PRINT USING 2550:M0
2640 PRINT "S3  MAXIMUM RANGE OF PROJECTILE (METERS,<=4000): ";
2650 PRINT USING 2660:S3
2660 IMAGE 4D
2670 PRINT "A   PLOTTING DEVISE (1=PEN PLOTTER, 32=SCREEN):";
2680 PRINT USING 2660:A
2690 PRINT "JJ"
2700 PRINT "G"
2710 PRINT "DO YOU WISH TO CHANGE ANY DATA (Y OR N): ";
2720 INPUT D$
2730 IF D$="Y" THEN 2780
2740 PRINT "ENTER 'Y' FOR MENU AND CALCULATIONS: ";
```

```
2750 INPUT B$
2760 IF B$="Y" THEN 2840
2770 GO TO 2830
2780 PRINT
2790 PRI "TO CHANGE DATA, TAKE VARIABLE NAME IN LEFT HAND COLUMN AND E";
2800 PRINT "QUATE IT TO "
2810 PRINT "NEW PARAMETER (i.e. B4=1).  TO VIEW NEW PARAMETERS PRESS U";
2820 PRINT "DK#10.  TO    CALCULATE VALUES PRESS UDK#11."
2830 END
2840 PAGE
2850 PRINT "PLEASE WAIT, CALCULATIONS IN PROGRESS"
2860 GOSUB 3150
2870 REM
2880 REM THIS IS THE MENU
2890 REM
2900 PAGE
2910 PRINT "                                USER DEFINABLE KEY DEFINITIONS"
2920 PRINT "JJJ"
2930 REM
2940 REM THIS IS THE MENU
2950 REM
2960 PRINT "1......NOMENCLATURE"
2970 PRINT "2......TABLE OF AERODYNAMIC COEFFICIENTS"
2980 PRINT "3......CDT vs. MACH NUMBER PLOT"
2990 PRINT "4......CNA vs. MACH NUMBER PLOT"
3000 PRINT "5......CMA vs. MACH NUMBER PLOT"
3010 PRINT "6......Cmq+Cm'α vs. MACH NUMBER PLOT"
3020 PRINT "7......CMPA vs. MACH NUMBER PLOT"
3030 PRINT "8......VELOCITY vs. RANGE PLOT"
3040 PRINT "9......SPIN STABILIZED PROJECTILE DESIGN"
3050 PRINT "10.....REVIEW AND CHANGE ORIGINAL DATA"
3060 PRINT "11.....CALCULATIONS"
3070 PRINT "12.....SET PARAMETERS FOR DIFFERENT PROJECTILE"
3080 PRINT "13.....RETURN TO MENU"
3090 PRINT
```

```
3100 PRINT
3110 PRINT
3120 PRINT "PLEASE PRESS USER DEFINABLE KEY TO CONTINUE"
3130 PRINT "G"
3140 END
3150 REM
3160 REM                    CALCULATIONS
3170 REM
3180 M=2
3190 L3=B3+D
3200 REM L3 IS THE AFTER BODY LENGTH
3210 L4=0.5-X4
3220 REM L4 IS THE RADIUS OF THE BASE
3230 FOR T=1 TO 13
3240 Q1(T)=M
3250 C1=0.4/(B4↑0.28*M↑0.53)
3260 C2=(0.15-0.03*M+0.01/M+1.0E-4*M↑3.6)*(L3/3+B4/4)
3270 C2=0.25*C2/M
3280 C3=2*(0.265-0.04*M)*L4↑2
3290 IF B6=0 THEN 3320
3300 C4=0.015
3310 GO TO 3330
3320 C4=0
3330 C=C1+C2+C3+C4
3340 N1=B4*(0.54+0.01*M)-L3*(0.015-0.02*M)
3350 H=N1
3360 REM  H IS CNASQ
3370 IF B3=0 THEN 3400
3380 H1=N1
3390 GO TO 3420
3400 H1=0
3410 REM H1=CNABT
3420 IF L1=0 THEN 3460
3430 N1=(1.24-0.071*M)*L1*N1
3440 H2=N1
```

```
3450 GO TO 3480
3460 REM H2 IS CNA(W/BOOM)
3470 H2=0
3480 REM N1 IS CNA  TOTAL
3490 M3=B4*0.67+0.0075*M+0.05*L3*M
3500 N9=L6-M3
3510 N0=N9*N1
3520 IF C$<>"Y" THEN 3540
3530 J=N0
3540 REM N9 IS THE STATIC MARGIN
3550 REM N0 IS CMA
3560 M1=(0.166*M-0.966)*B4-(0.237*M+1.91)*L3
3570 M2=(0.07375-0.01875*M)*B4+(0.0263*M-0.01)*L3+0.02*B3
3580 REM M2 IS CMPA
3590 REM M3 IS THE CP OF NORMAL FORCE FOR A CONICAL PROJECTILE
3600 Q(1,T)=C1
3610 Q(2,T)=C2
3620 Q(3,T)=C3
3630 Q(4,T)=C4
3640 Q(5,T)=C
3650 Q(6,T)=H
3660 Q(7,T)=N1
3670 Q(8,T)=M1
3680 Q(9,T)=M2
3690 Q(10,T)=M3
3700 Q(11,T)=N0
3710 M=M+0.25
3720 NEXT T
3730 IF C$<>"Y" THEN 3940
3740 A1=PI/4
3750 K=Q(5,9)-Q(5,5)
3760 B0=-(K*3)+Q(5,5)
3770 Q2=R0*A1*B0/(2*M5)
3780 R4=(K*M0+B0)/M0
3790 S=I1↑2*2*(2*PI/N)↑2/(PI*R0*I2*N0)
```

```
3800 S1=2*PI/((I1/I2)↑2*(2*PI/N)↑2-PI*R0/(2*I2*J))↑0.5
3810 S2=0
3820 FOR T=1 TO 17
3830 V=B0/(R4*EXP(Q2*S2/(D6/1000))-K)*340.29
3840 J1(T)=V
3850 S2=S2+250
3860 IF S2>S3 THEN 3880
3870 NEXT T
3880 K1=S3/250+1
3890 FOR T=2 TO K1
3900 J2(T)=(J1(1)-J1(T))/(T-1)/250*1000
3910 IF J1(T)=V THEN 3930
3920 NEXT T
3930 J2(1)=J2(2)
3940 RETURN
3950 REM
3960 REM NOMENCLATURE
3970 REM
3980 PAGE
3990 PRINT
4000 PRINT "                              NOMENCLATURE"
4010 PRINT "JJJ"
4020 PRINT "CDWB       Coefficient of wave drag for the projectile body"
4030 PRINT "CDVB       Visvous drag coefficient for the projectile body"
4040 PRINT "CDBB       Base drag coefficient for the projectile body"
4050 PRI "CDRB      Rotating band drag coefficient for the projectile";
4060 PRINT " body"
4070 PRINT "CDT        Total drag coefficient for the projectile body"
4080 PRI "CNASQ     Normal force slope coefficient for a square based";
4090 PRINT " projectile"
4100 PRI "CNABT     Normal force coefficient for boattailed projectile"
4110 PRI "CNABE     Normal force slope coefficient with boom extension"
4120 PRINT "CNAT       Total normal force slope coefficient"
4130 PRINT "Cmq+Cm'a   Damping moment slope coefficient"
4140 PRINT "CMPA       Magnus moment slope coefficient"
```

```
4150 PRINT "CP          Center of pressure of the normal force"
4160 PRINT "CMA         Static moment slope coefficient"
4170 PRINT "G"
4180 END
4190 REM THIS IS THE TABLE OF CALCULATIONS
4200 REM
4210 PAGE
4220 PRINT "   STATIC AERODYNAMIC COEFFICIENTS FOR SPIN STABILIZED";
4230 PRINT " PROJECTILES"
4240 PRINT
4250 PRINT USING 4260:"MACH NUMBER"
4260 IMAGE 30X,11A
4270 PRINT
4280 PRINT USING 4290:"2.0","2.5","3.0","3.5","4.0","4.5","5.0"
4290 IMAGE   12X,3A,6X,3A,7X,3A,7X,4(3A,6X)
4300 PRINT "CDWB"
4310 PRINT "CDVB"
4320 PRINT "CDBB"
4330 PRINT "CDRB"
4340 PRINT "CDT"
4350 PRINT "CNASQ"
4360 PRINT "CNAT"
4370 PRINT "Cmq+Cm`a"
4380 PRINT "CMPA"
4390 PRINT "CP"
4400 PRINT "CMA"
4410 HOME
4420 PRINT "JJJJJ"
4430 FOR T=1 TO 11
4440 PRINT USING 4450:Q(T,1),Q(T,3),Q(T,5),Q(T,7),Q(T,9),Q(T,11),Q(T,13)
4450 IMAGE 8X,2(4D.3D,1X),2(1X,4D.3D,1X),2(4D.3D,1X),4D.3D
4460 NEXT T
4470 PRINT "G"
4480 END
4490 REM
```

```
4500 REM THIS IS THE GRAPH OF CDT vs. MACH NUMBER
4510 REM
4520 PAGE
4530 VIEWPORT 20,125,12,90
4540 WINDOW 1.75,5,0,0.5
4550 AXIS @A:0.25,0.025
4560 MOVE @A:2,0
4570 RMOVE @A:-0.07,-0.025
4580 PRINT @A:"2.0"
4590 FOR R=3 TO 5
4600 RMOVE @A:1,0
4610 PRINT @A: USING 4620:R
4620 IMAGE 1D.1D
4630 NEXT R
4640 MOVE @A:1.75,0.1
4650 RMOVE @A:-0.2,-0.007
4660 PRINT @A:"0.1"
4670 FOR R=0.2 TO 0.5 STEP 0.1
4680 RMOVE @A:0,0.1
4690 PRINT @A: USING 4700:R
4700 IMAGE 1D.1D
4710 NEXT R
4720 PRINT @A:"JJJJJJJJJJJ"
4730 PRINT @A: USING 4740:"CDT"
4740 IMAGE 5X,3A
4750 PRINT @A:"JJJJJJJJJJJJJJJ"
4760 PRINT @A: USING 4770:"MACH No."
4770 IMAGE 38X,8A
4780 MOVE @A:2,0
4790 RMOVE @A:-0.016,0.005
4800 PRINT @A:"|"
4810 FOR R=3 TO 5
4820 RMOVE @A:1,0
4830 PRINT @A:"|"
4840 NEXT R
```

```
4850 MOVE @A:1.75,0.1
4860 IF A<>1 THEN 4890
4870 RMOVE @A:0.04,-0.0053
4880 GO TO 4900
4890 RMOVE @A:0.04,-0.0073
4900 PRINT @A:"-"
4910 FOR R=0.2 TO 0.5 STEP 0.1
4920 RMOVE @A:0,0.1
4930 PRINT @A:"-"
4940 NEXT R
4950 HOME @A:
4960 PRINT @A: USING 4970:"CDT vs. MACH No."
4970 IMAGE 35X,16A
4980 MOVE @A:Q1(1),Q(5,1)
4990 FOR R=2 TO 13
5000 DRAW @A:Q1(R),Q(5,R)
5010 NEXT R
5020 PRINT "G"
5030 END
5040 REM
5050 REM THIS IS THE GRAPH OF CNA vs. MACH No.
5060 REM
5070 PAGE
5080 VIEWPORT 20,125,12,90
5090 WINDOW 1.75,5,0.5,6
5100 AXIS @A:0.25,0.1
5110 MOVE @A:2,0.5
5120 RMOVE @A:-0.07,-0.23
5130 PRINT @A:"2.0"
5140 FOR R=3 TO 5
5150 RMOVE @A:1,0
5160 PRINT @A: USING 5170:R
5170 IMAGE 1D.1D
5180 NEXT R
5190 MOVE @A:1.75,1
```

```
5200 RMOVE @A:-0.2,-0.045
5210 PRINT @A:"1.0"
5220 FOR R=2 TO 6
5230 RMOVE @A:0,1
5240 PRINT @A: USING 5250:R
5250 IMAGE 1D.1D
5260 NEXT R
5270 MOVE @A:2,0.5
5280 RMOVE @A:-0.017,0.025
5290 PRINT @A:"|"
5300 FOR R=3 TO 5
5310 RMOVE @A:1,0
5320 PRINT @A:"|"
5330 NEXT R
5340 MOVE @A:1.75,1
5350 IF A<>1 THEN 5380
5360 RMOVE @A:0.027,-0.06
5370 GO TO 5390
5380 RMOVE @A:0.027,-0.08
5390 PRINT @A:"-"
5400 FOR R=1.5 TO 6 STEP 0.5
5410 RMOVE @A:0,0.5
5420 PRINT @A:"-"
5430 NEXT R
5440 HOME @A:
5450 PRINT @A: USING 5460:"CHAT vs. MACH No."
5460 IMAGE 35X,17A
5470 PRINT @A:"JJJJJJJJJJJJJJJJ"
5480 PRINT @A: USING 5490:"CHAT"
5490 IMAGE 4X,4A
5500 PRINT @A:"JJJJJJJJJJJJJJJ"
5510 PRINT @A: USING 5520:"MACH No."
5520 IMAGE 38X,8A
5530 MOVE @A:Q1(1),Q(7,1)
5540 FOR R=2 TO 13
```

```
5550 DRAW @A:Q1(R),Q(7,R)
5560 NEXT R
5570 HOME @A:
5580 PRINT "G"
5590 END
5600 REM
5610 REM THIS IS THE GRAPH OF CMA vs. MACH No.
5620 REM
5630 PAGE
5640 VIEWPORT 20,125,12,90
5650 WINDOW 1.75,5,0,6
5660 AXIS @A:0.25,0.25
5670 MOVE @A:2,0
5680 RMOVE @A:-0.062,-0.3
5690 PRINT @A:"2.0"
5700 FOR R=3 TO 5
5710 RMOVE @A:1,0
5720 PRINT @A: USING 5730:R
5730 IMAGE 1D.1D
5740 NEXT R
5750 MOVE @A:1.75,1
5760 RMOVE @A:-0.2,-0.08
5770 PRINT @A:"1.0"
5780 FOR R=2 TO 6
5790 RMOVE @A:0,1
5800 PRINT @A: USING 5810:R
5810 IMAGE 1D.1D
5820 NEXT R
5830 MOVE @A:2,0
5840 RMOVE @A:-0.018,0
5850 PRINT @A:"|"
5860 FOR R=3 TO 5
5870 RMOVE @A:1,0
5880 PRINT @A:"|"
5890 NEXT R
```

```
5900 MOVE @A:1.75,1
5910 IF A<>1 THEN 5940
5920 RMOVE @A:0.03,-0.065
5930 GO TO 5950
5940 RMOVE @A:0.03,-0.095
5950 PRINT @A:"-"
5960 FOR R=2 TO 6
5970 RMOVE @A:0,1
5980 PRINT @A:"-"
5990 NEXT R
6000 HOME @A:
6010 PRINT @A: USING 6020:"CMA vs. MACH No."
6020 IMAGE 35X,17A
6030 PRINT @A:"JJJJJJJJJJJJJ"
6040 PRINT @A: USING 6050:"CMA"
6050 IMAGE 5X,3A
6060 PRINT @A:"JJJJJJJJJJJJJJJJ"
6070 PRINT @A: USING 6080:"MACH No."
6080 IMAGE 33X,8A
6090 MOVE @A:Q1(1),Q(11,1)
6100 FOR R=2 TO 13
6110 DRAW @A:Q1(R),Q(11,R)
6120 NEXT R
6130 HOME @A:
6140 PRINT "G"
6150 END
6160 REM
6170 REM THIS IS THE GRAPH OF CMQ+CMA vs. MACH No.
6180 REM
6190 PAGE
6200 VIEWPORT 20,125,12,90
6210 WINDOW 1.75,5,0,20
6220 AXIS @A:0.25,0.5
6230 MOVE @A:2,0
6240 RMOVE @A:-0.07,-0.85
```

```
6250 PRINT @A:"2.0"
6260 FOR R=3 TO 5
6270 RMOVE @A:1,0
6280 PRINT @A: USING 6290:R
6290 IMAGE 1D.1D
6300 NEXT R
6310 MOVE @A:1.75,2
6320 RMOVE @A:-0.2,-0.014
6330 PRINT @A:"2.0"
6340 FOR R=4 TO 9 STEP 2
6350 RMOVE @A:0,2
6360 PRINT @A: USING 6370:R
6370 IMAGE 1D.1D
6380 NEXT R
6390 MOVE @A:1.75,10
6400 RMOVE @A:-0.25,-0.014
6410 PRINT @A:"10.0"
6420 FOR R=12 TO 20 STEP 2
6430 RMOVE @A:0,2
6440 PRINT @A: USING 6450:R
6450 IMAGE 2D.1D
6460 NEXT R
6470 PRINT @A:"JJJJJJJJJJJ"
6480 PRINT @A: USING 6510:"Cmq"
6490 PRINT @A: USING 6510:" +"
6500 PRINT @A: USING 6510:"Cm'α"
6510 IMAGE 2X,4A
6520 PRINT @A:"JJJJJJJJJJJJJ"
6530 PRINT @A: USING 6540:"MACH No."
6540 IMAGE 38X,8A
6550 MOVE @A:2,0
6560 RMOVE @A:-0.016,0.005
6570 PRINT @A:"I"
6580 FOR R=3 TO 5
6590 RMOVE @A:1,0
```

```
6600 PRINT @A:"I"
6610 NEXT R
6620 MOVE @A:1.75,2
6630 IF A<>1 THEN 6660
6640 RMOVE @A:0.04,-0.2
6650 GO TO 6670
6660 RMOVE @A:0.04,-0.3
6670 PRINT @A:"-"
6680 FOR R=4 TO 20 STEP 2
6690 RMOVE @A:0,2
6700 PRINT @A:"-"
6710 NEXT R
6720 MOVE @A:1.75,2
6730 RMOVE @A:-0.25,-0.03
6740 PRINT @A:"-"
6750 FOR R=4 TO 9 STEP 2
6760 RMOVE @A:0,2
6770 PRINT @A:"-"
6780 NEXT R
6790 MOVE @A:1.75,10
6800 RMOVE @A:-0.3,-0.03
6810 PRINT @A:"-"
6820 FOR R=12 TO 20 STEP 2
6830 RMOVE @A:0,2
6840 PRINT @A:"-"
6850 NEXT R
6860 HOME @A:
6870 PRINT @A: USING 6880:"Cmq+Cm'α vs. MACH No."
6880 IMAGE 32X,21A
6890 MOVE @A:Q1(1),ABS(Q(8,1))
6900 FOR R=2 TO 13
6910 DRAW @A:Q1(R),ABS(Q(8,R))
6920 NEXT R
6930 PRINT @A:"G"
6940 END
```

```
6950 REM
6960 REM THIS IS THE GRAPH OF CMPA vs. MACH No.
6970 REM
6980 PAGE
6990 VIEWPORT 20,125,12,90
7000 WINDOW 1.75,5,0,1
7010 AXIS @A:0.25,0.025
7020 MOVE @A:2,0
7030 RMOVE @A:-0.07,-0.05
7040 PRINT @A:"2.0"
7050 FOR R=3 TO 5
7060 RMOVE @A:1,0
7070 PRINT @A: USING 7080:R
7080 IMAGE1D.1D
7090 NEXT R
7100 MOVE @A:1.75,0.1
7110 RMOVE @A:-0.2,-0.014
7120 PRINT @A:"0.1"
7130 FOR R=0.2 TO 1 STEP 0.1
7140 RMOVE @A:0,0.1
7150 PRINT @A: USING 7160:R
7160 IMAGE 1D.1D
7170 NEXT R
7180 PRINT @A:"JJJJJJJJJJJ"
7190 PRINT @A: USING 7200:"CMPA"
7200 IMAGE3X,4A
7210 PRINT @A:"JJJJJJJJJJJJJJJ"
7220 PRINT @A: USING 7230:"MACH No."
7230 IMAGE 38X,8A
7240 MOVE @A:2,0
7250 RMOVE @A:-0.017,0.01
7260 PRINT @A:"I"
7270 FOR R=3 TO 5
7280 RMOVE @A:1,0
7290 PRINT @A:"I"
```

```
7300 NEXT R
7310 MOVE @A:1.75,0.1
7320 IF A<>1 THEN 7350
7330 RMOVE @A:0.04,-0.01
7340 GO TO 7360
7350 RMOVE @A:0.04,-0.0146
7360 PRINT @A:"-"
7370 FOR R=0.2 TO 1 STEP 0.1
7380 RMOVE @A:0,0.1
7390 PRINT @A:"-"
7400 NEXT R
7410 HOME @A:
7420 PRINT @A: USING 7430:"CMPA vs. MACH No."
7430 IMAGE 32X,17A
7440 MOVE @A:Q1(1),Q(9,1)
7450 FOR R=2 TO 13
7460 DRAW @A:Q1(R),Q(9,R)
7470 NEXT R
7480 PRINT "G"
7490 END
7500 REM
7510 REM THIS IS THE GRAPH OF VELOCITY vs. RANGE
7520 REM
7530 PAGE
7540 IF C$<>"Y" THEN 8350
7550 VIEWPORT 20,125,40,90
7560 WINDOW 0,4,0,2000
7570 AXIS @A:0.25,100
7580 MOVE @A:0.5,0
7590 RMOVE @A:-0.08,-135
7600 PRINT @A:"0.5"
7610 FOR R=1 TO 4 STEP 0.5
7620 RMOVE @A:0.5,0
7630 PRINT @A: USING 7640:R
7640 IMAGE 1D.1D
```

```
7650 NEXT R
7660 MOVE @A:0,500
7670 RMOVE @A:-0.31,-30
7680 PRINT @A:"500"
7690 FOR R=1000 TO 2000 STEP 500
7700 RMOVE @A:0,500
7710 PRINT @A: USING 7720:R
7720 IMAGE 4D
7730 NEXT R
7740 MOVE @A:0.5,0
7750 RMOVE @A:-0.0195,0
7760 PRINT @A:"|"
7770 FOR R=1 TO 4 STEP 0.5
7780 RMOVE @A:0.5,0
7790 PRINT @A:"|"
7800 NEXT R
7810 MOVE @A:0,500
7820 IF A<>1 THEN 7850
7830 RMOVE @A:0.05,-33
7840 GO TO 7860
7850 RMOVE @A:0.05,-50
7860 PRINT @A:"-"
7870 FOR R=1000 TO 2000 STEP 500
7880 RMOVE @A:0,500
7890 PRINT @A:"-"
7900 NEXT R
7910 HOME @A:
7920 PRINT @A: USING 7930:"VELOCITY vs. RANGE"
7930 IMAGE 32X,18A
7940 IF A<>1 THEN 8020
7950 MOVE @A:-0.5,700
7960 PRINT @1,25:90
7970 PRINT @A: USING 7980:"VELOCITY (M/S)"
7980 IMAGE 14A
7990 PRINT @1,7:
```

```
8000 PRINT @A:"JJJJJJJJ"
8010 GO TO 8080
8020 PRINT @A:"JJJJJJJJ"
8030 PRINT @A: USING 8040:"VEL"
8040 IMAGE 2X,11A
8050 PRINT @A: USING 8060:"(M/SEC)"
8060 IMAGE 8A
8070 PRINT @A:"JJJJJJJJJJJ"
8080 PRINT @A: USING 8090:"RANGE(KM)"
8090 IMAGE 37X,9A
8100 HOME @A:
8110 PRINT @A:"J"
8120 PRINT @A: USING 8130:"GYROSCOPIC STABILITY FACTOR: ",S
8130 IMAGE 2X,29A,2D.3D
8140 HOME @A:
8150 PRINT @A:"J"
8160 PRINT @A: USING 8170:"INITIAL YAW CYCLE: ",S1," CAL"
8170 IMAGE 40X,19A,3D.2D,4A
8180 J3=0
8190 MOVE @A:0,J1(1)
8200 FOR R=1 TO 17
8210 DRAW @A:J3/1000,J1(R)
8220 IF J1(R)=V THEN 8250
8230 J3=J3+250
8240 NEXT R
8250 MOVE @A:0,0
8260 PRINT @A:"JJJJ"
8270 FOR S2=0 TO S3/250+1 STEP 2
8280 IF K1<=S2 THEN 8320
8290 PRINT @A: USING 8300:S3-S2*250,J2(K1-S2)
8300 IMAGE 15X,"RANGE: ",4D," KM",10X,"RETARDATION: ",4D.3D," (M/S)/KM"
8310 NEXT S2
8320 HOME
8330 PRINT "G"
8340 GO TO 8360
```

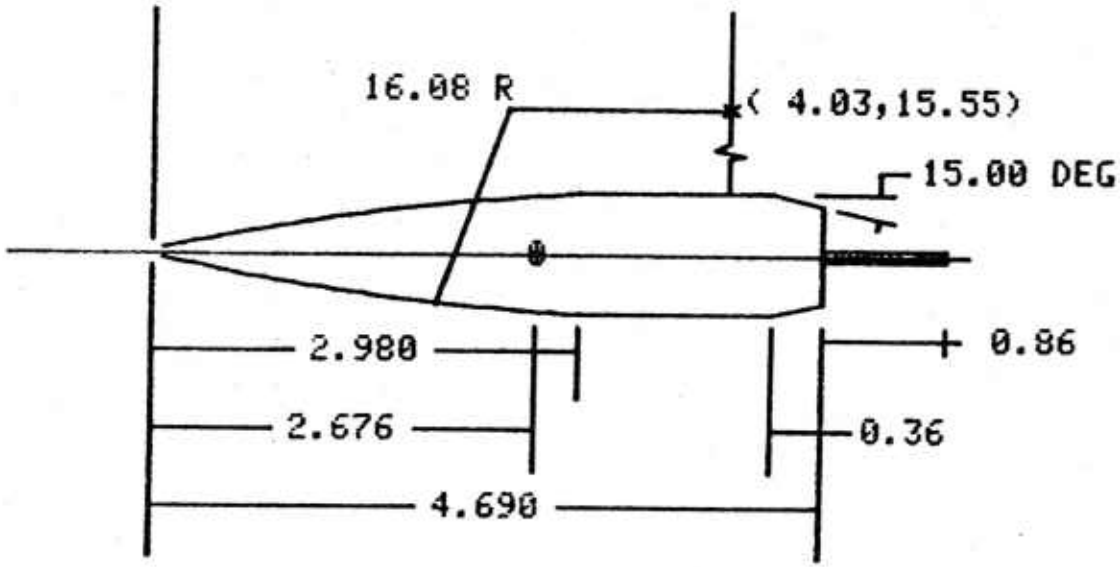
```
8350 PRINT "NO PARAMETERS WERE GIVEN FOR VELOCITY vs. RANGE PLOT"
8360 END
8370 PAGE
8380 PRINT
8390 PRINT "DO YOU WISH TO VIEW ANOTHER PROJECTILE (Y OR N): ";
8400 INPUT F$
8410 IF F$<>"Y" THEN 8500
8420 PRINT
8430 PRINT "WILL THE NEW PROJECTILE HAVE A CONICAL NOSE (Y OR N): ";
8440 INPUT G$
8450 IF G$="Y" THEN 100
8460 PRINT
8470 PRINT "LOADING PROGRAM FOR OGIVAL PROJECTILE"
8480 FIND 2
8490 OLD
8500 END
```

APPENDIX B

M-392 PROJECTILE CHARACTERISTICS

```
ALL VALUES ARE IN CALIBERS UNLESS OTHERWISE NOTED

B4      OGIVE LENGTH:  2.98
B5      OGIVE RADIUS: 16.08
D       CYLINDRICAL BODY LENGTH:  1.35
L6      CENTER OF GRAVITY OF PROJECTILE (NOSE):  2.68
B3      BOATTAIL LENGTH:  0.36
D2,D1   BOATTAIL ANGLE (DEGREES,MINUTES): 15.00
B6      ROTATING BAND RADIUS:  0.00
D3      ROTATING BAND WIDTH:  0.00
L7      DISTANCE TO ROTATING BAND FROM BASE:  0.00
L1      LENGTH OF BOOM EXTENTION:  0.86
I1      AXIAL MOMENT OF INERTIA (CAL↑5):    1.38
I2      TRANSVERSE MOMENT OF INERTIA (CAL↑5):   13.02
M5      WEIGHT OF PROJECTILE (CAL↑3):    8.80
N       TWIST OF PROJECTILE (NO. OF CAL/REV): 31.00
D6      DIAMETER OF PROJECTILE (MM): 61.000
R0      DENSITY OF AIR (g/cc): 0.001225
M0      MUZZLE MACH NUMBER:  4.72
S3      MAXIMUM RANGE OF PROJECTILE (METERS,<=4000): 4000
A       PLOTTING DEVISE (1=PEN PLOTTER, 32=SCREEN):  32



DO YOU WISH TO CHANGE ANY DATA (Y OR N):
```

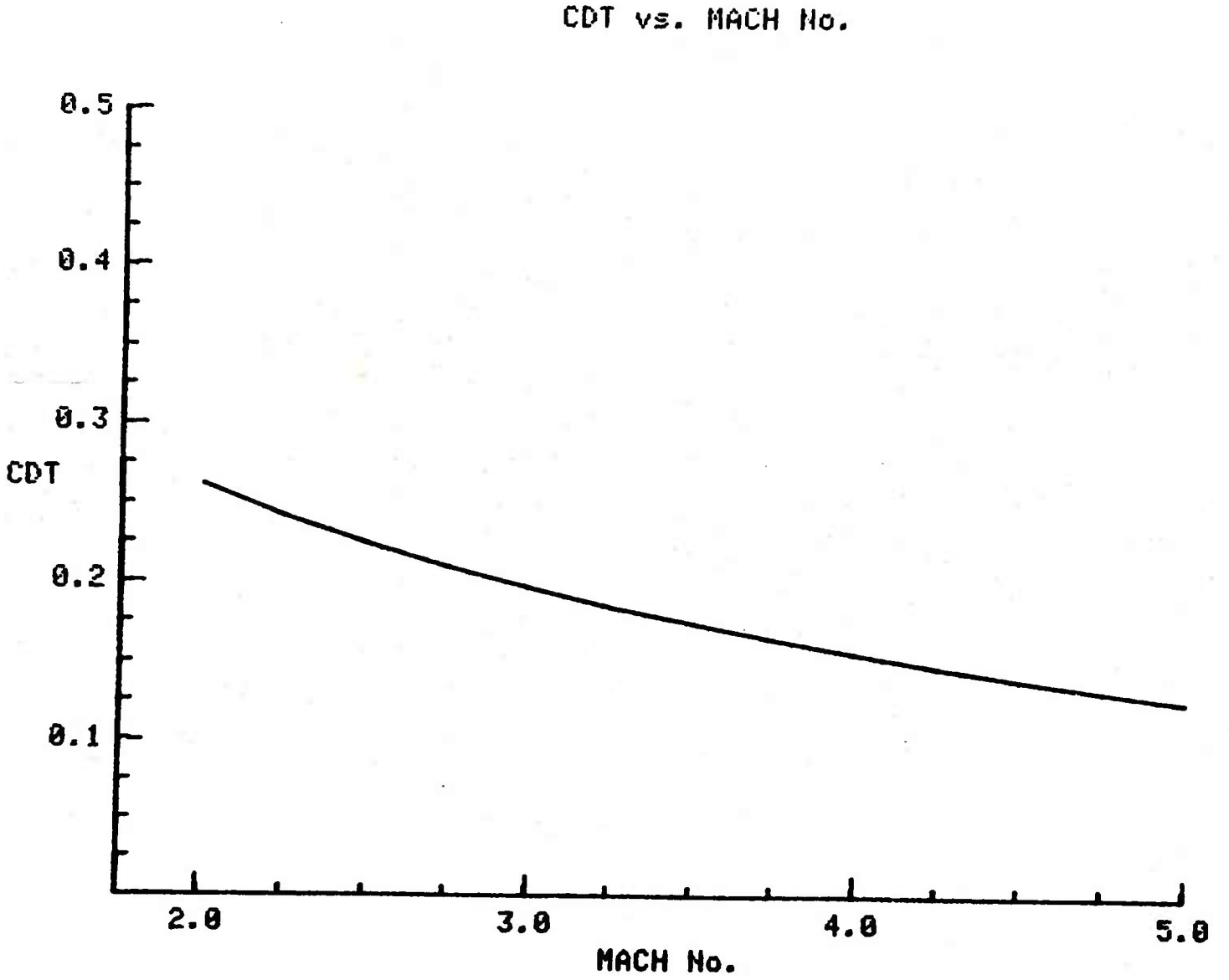
SECANT OGIVE CYLINDER BOATTAIL PROJECTILE DESIGN

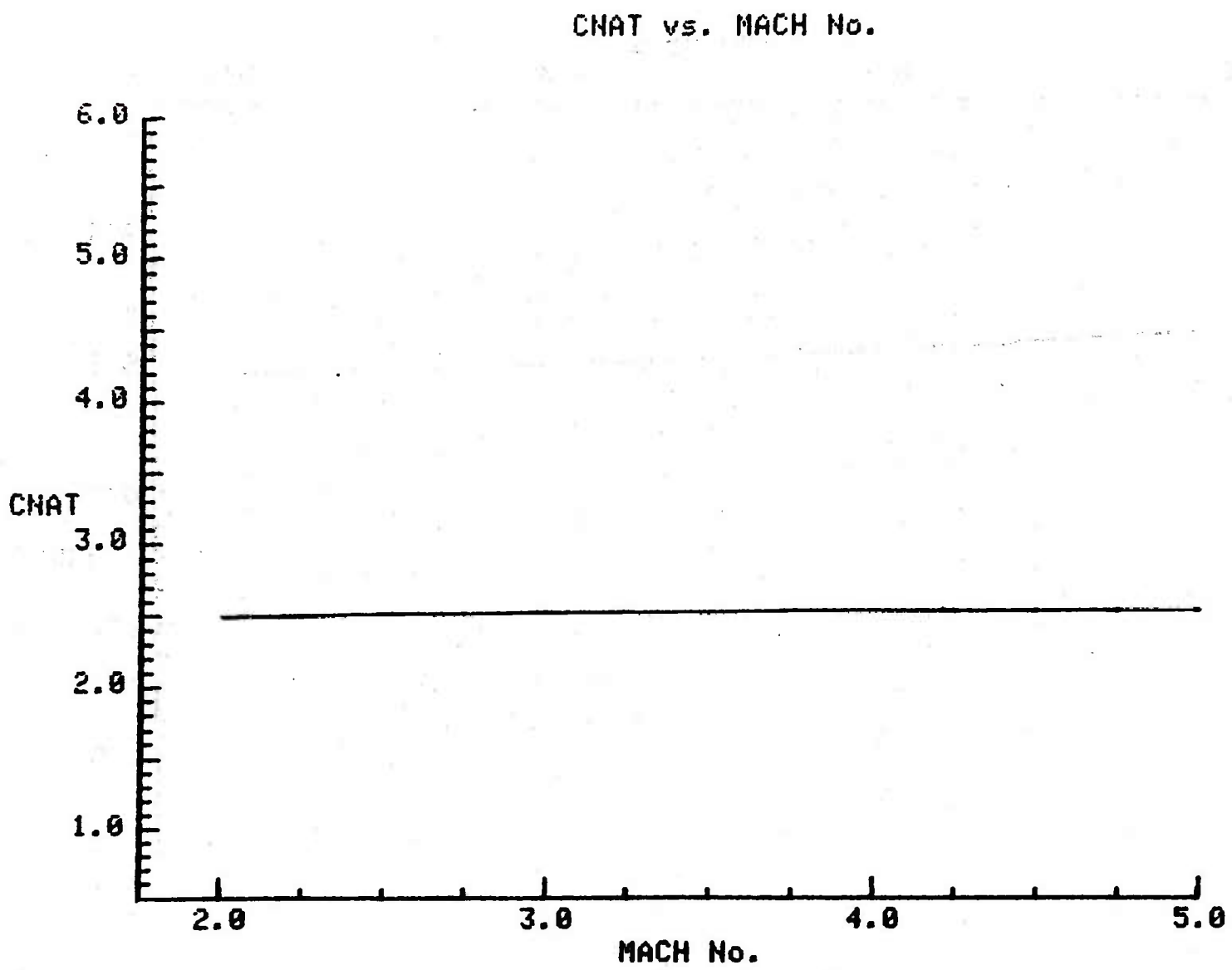


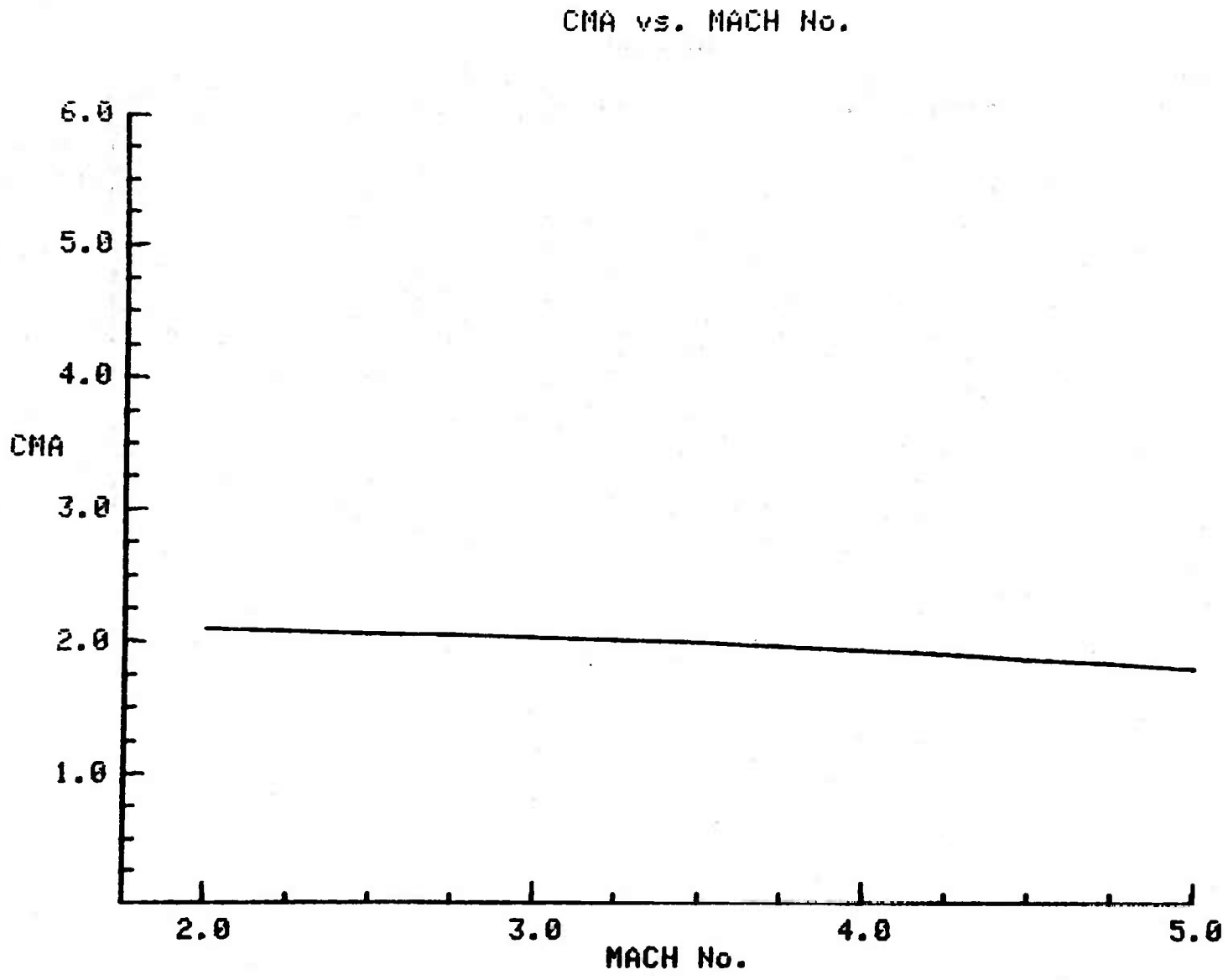
IF YOU WANT INITIAL DATA PRINTED OUT OR CHANGED ENTER 'Y':

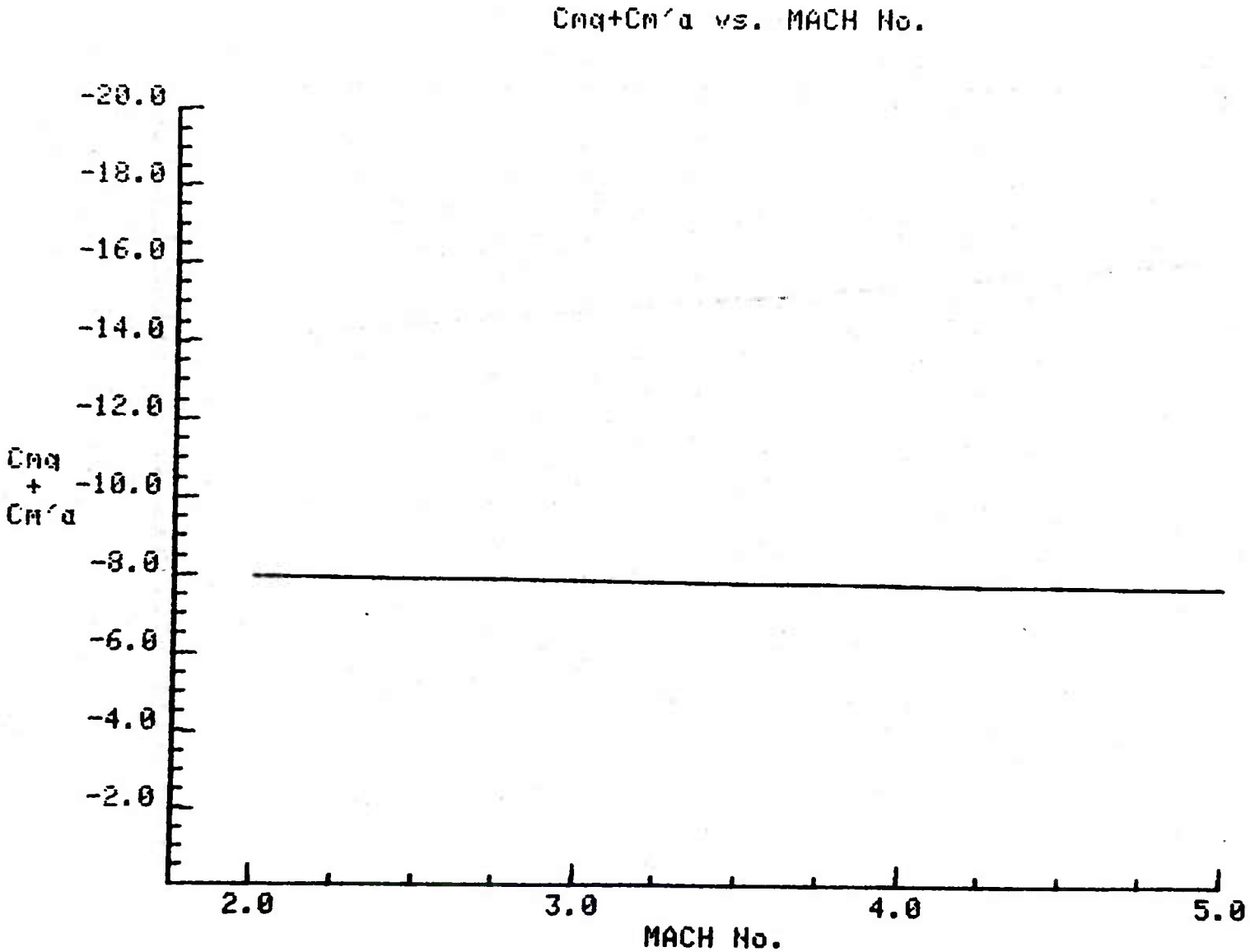
AERODYNAMIC COEFFICIENTS FOR SPIN STABILIZED PROJECTILES

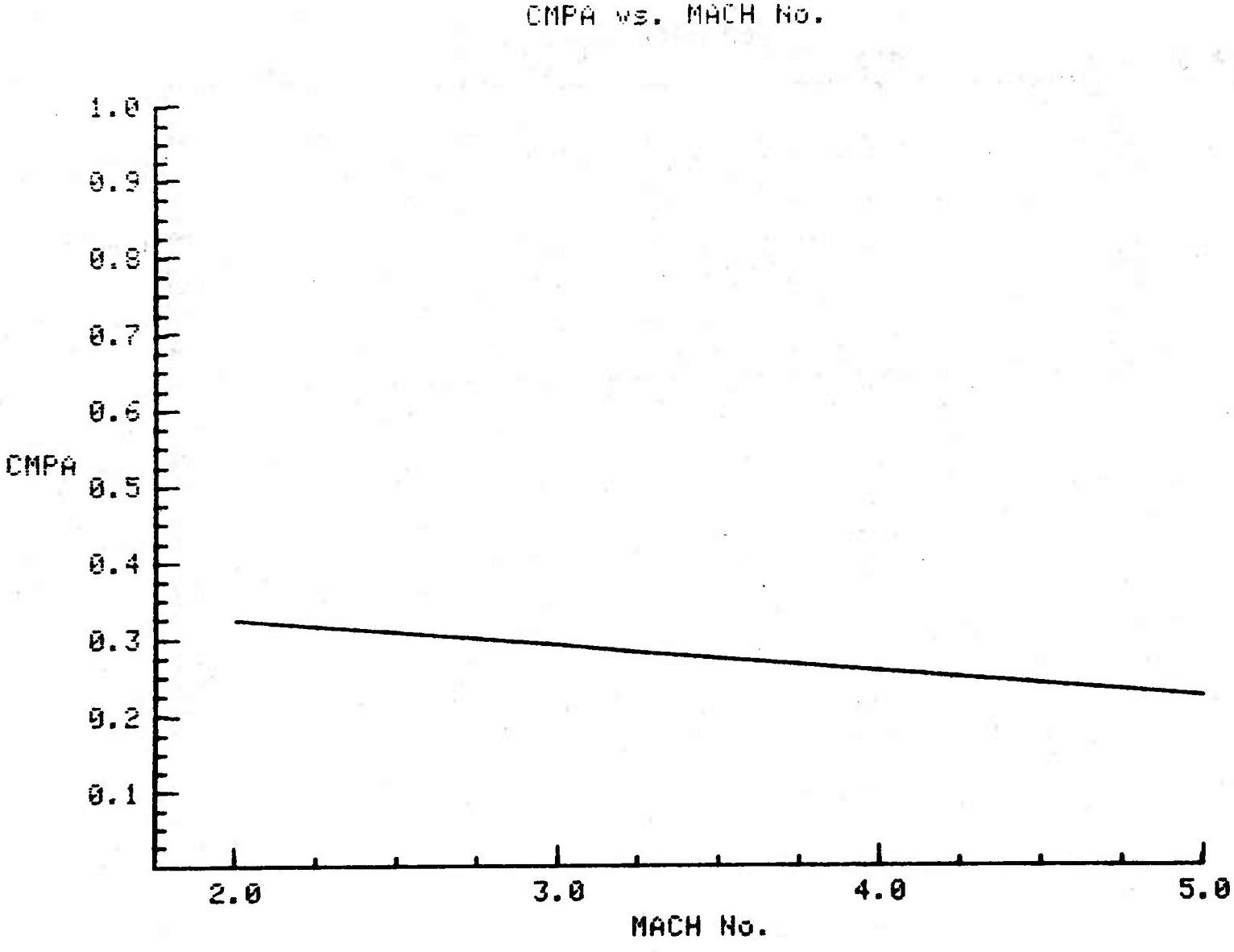
	MACH NUMBER						
	2.0	2.5	3.0	3.5	4.0	4.5	5.0
CDWB	0.159	0.141	0.128	0.118	0.110	0.104	0.098
CDUB	0.042	0.028	0.020	0.014	0.010	0.008	0.006
CDBB	0.060	0.054	0.047	0.041	0.034	0.028	0.021
CDRB	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CDT	0.261	0.224	0.195	0.173	0.155	0.139	0.125
CNASQ	3.070	3.240	3.406	3.572	3.739	3.910	4.085
CNABT	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CNABE	2.496	2.508	2.516	2.523	2.527	2.529	2.529
CNAT	2.496	2.508	2.516	2.523	2.527	2.529	2.529
Cmq+Cm`a	-7.944	-7.899	-7.854	-7.810	-7.765	-7.720	-7.676
CMPA	0.188	0.183	0.177	0.172	0.166	0.161	0.155
CP(NOSE)	3.513	3.495	3.479	3.460	3.438	3.411	3.382
CMA	2.089	2.054	2.021	1.979	1.925	1.860	1.785


CDT vs. MACH No.
0.5
0.4
0.3
CDT
0.2
0.1
2.0
3.0
4.0
5.0
MACH No.


CNAT vs. MACH No.
6.0
5.0
4.0
CNAT
3.0
2.0
1.0
2.0
3.0
4.0
5.0
MACH No.

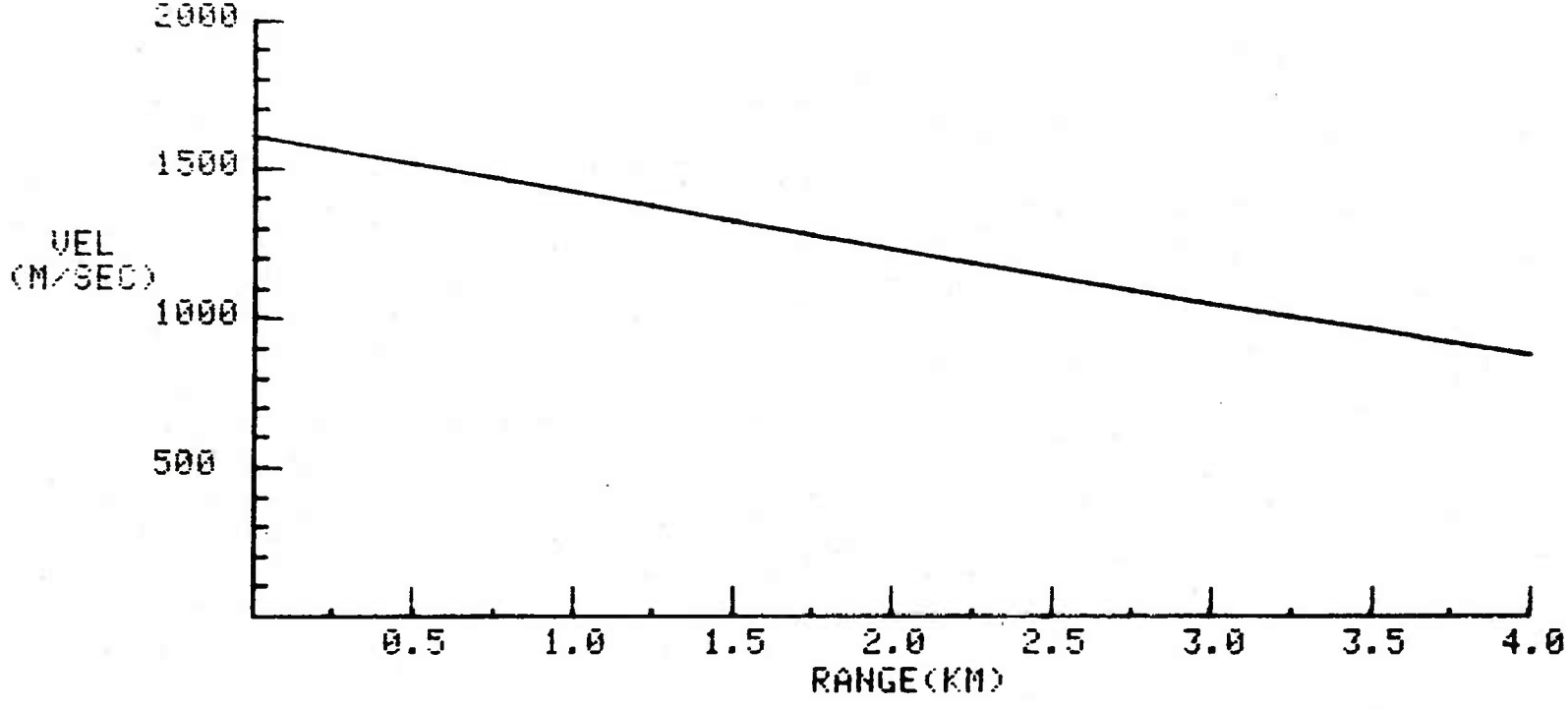

CMA vs. MACH No.
6.0
5.0
4.0
CMA
3.0
2.0
1.0
2.0
3.0
4.0
5.0
MACH No.


Cmq+Cm'a vs. MACH No.
-20.0
-18.0
-16.0
-14.0
-12.0
Cmq
+
Cm'a
-10.0
-8.0
-6.0
-4.0
-2.0
2.0
3.0
4.0
5.0
MACH No.


CMPA vs. MACH No.
CMPA
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
2.0
3.0
4.0
5.0
MACH No.

VELOCITY vs. RANGE

GYROSCOPIC STABILITY FACTOR: 1.611 INITIAL YAW CYCLE: 474.97 CAL

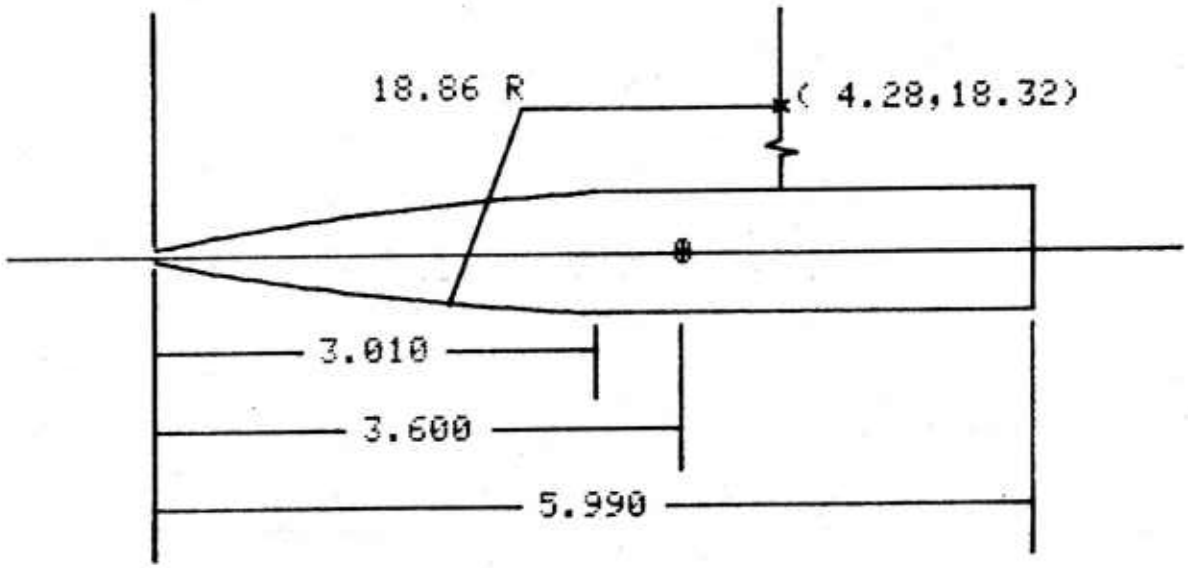


RANGE:	4000 KM	RETARDATION:	183.121 (M/S)/KM
RANGE:	3500 KM	RETARDATION:	184.881 (M/S)/KM
RANGE:	3000 KM	RETARDATION:	186.084 (M/S)/KM
RANGE:	2500 KM	RETARDATION:	186.694 (M/S)/KM
RANGE:	2000 KM	RETARDATION:	186.684 (M/S)/KM
RANGE:	1500 KM	RETARDATION:	186.044 (M/S)/KM
RANGE:	1000 KM	RETARDATION:	184.778 (M/S)/KM
RANGE:	500 KM	RETARDATION:	182.905 (M/S)/KM
RANGE:	0 KM	RETARDATION:	181.751 (M/S)/KM

APPENDIX C

CHARACTERISTICS OF PROJECTILES WITH VARIOUS BOAT TAILS

OGIVE CYLINDER PROJECTILE DESIGN

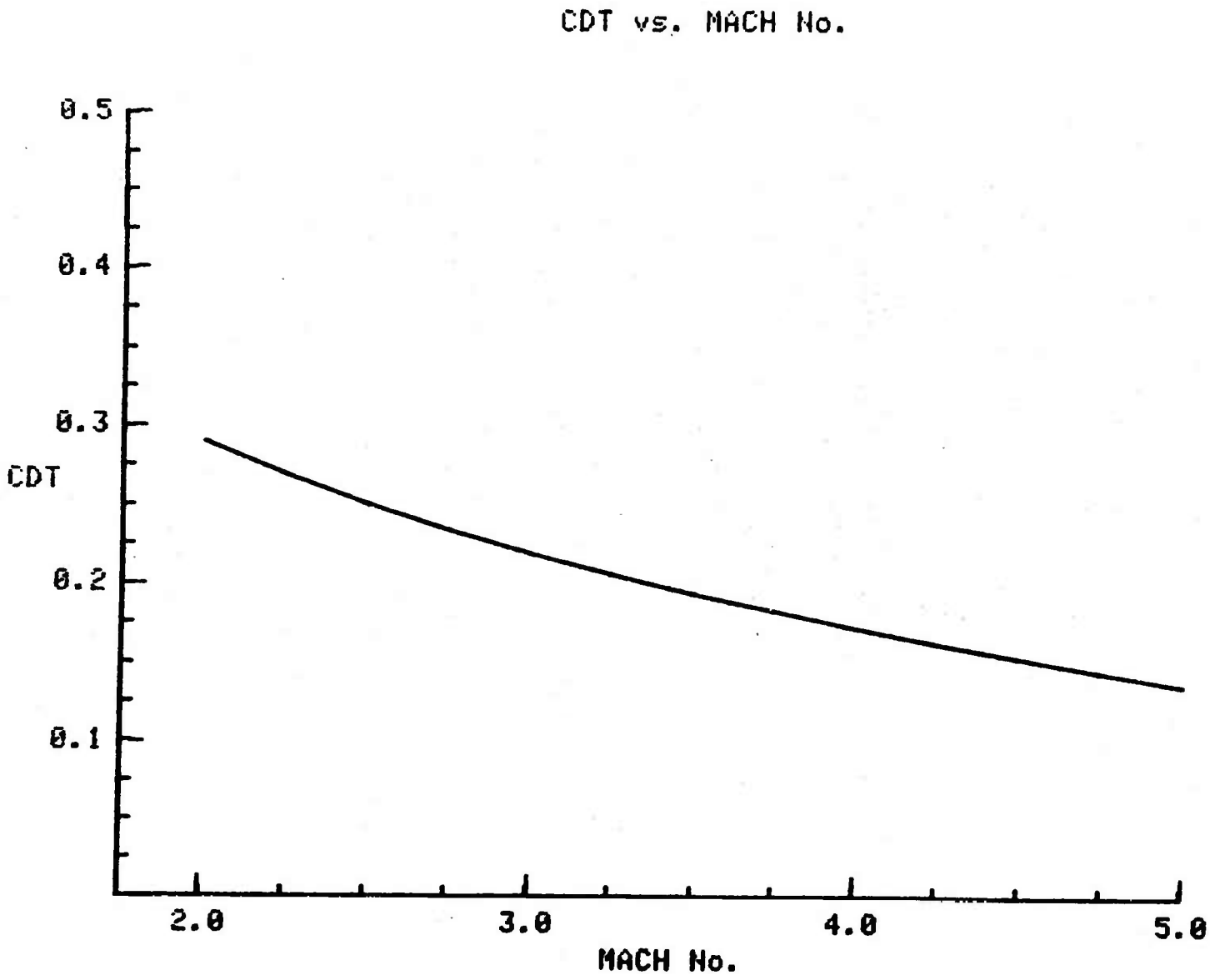


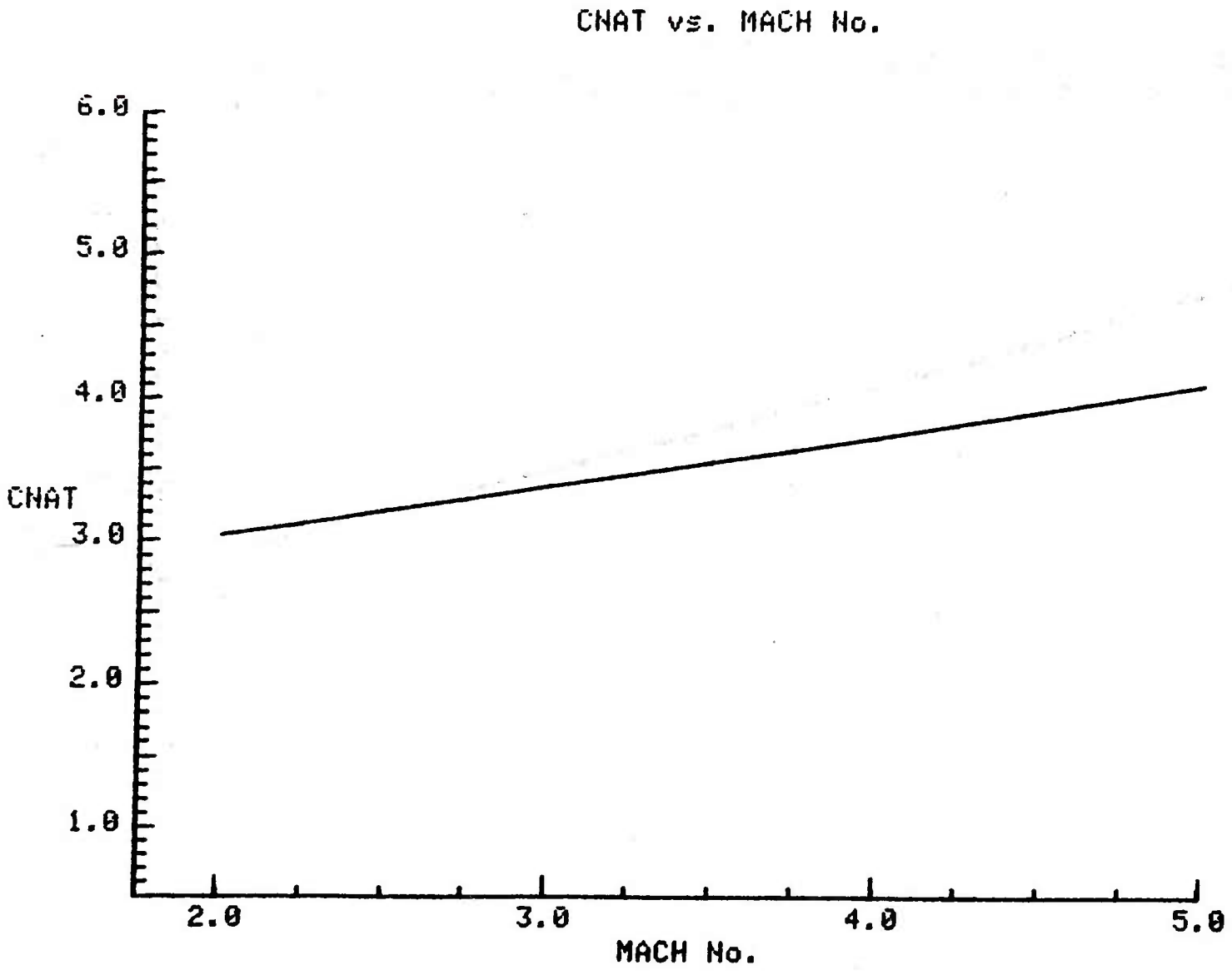
IF YOU WANT INITIAL DATA PRINTED OUT OR CHANGED ENTER 'Y':

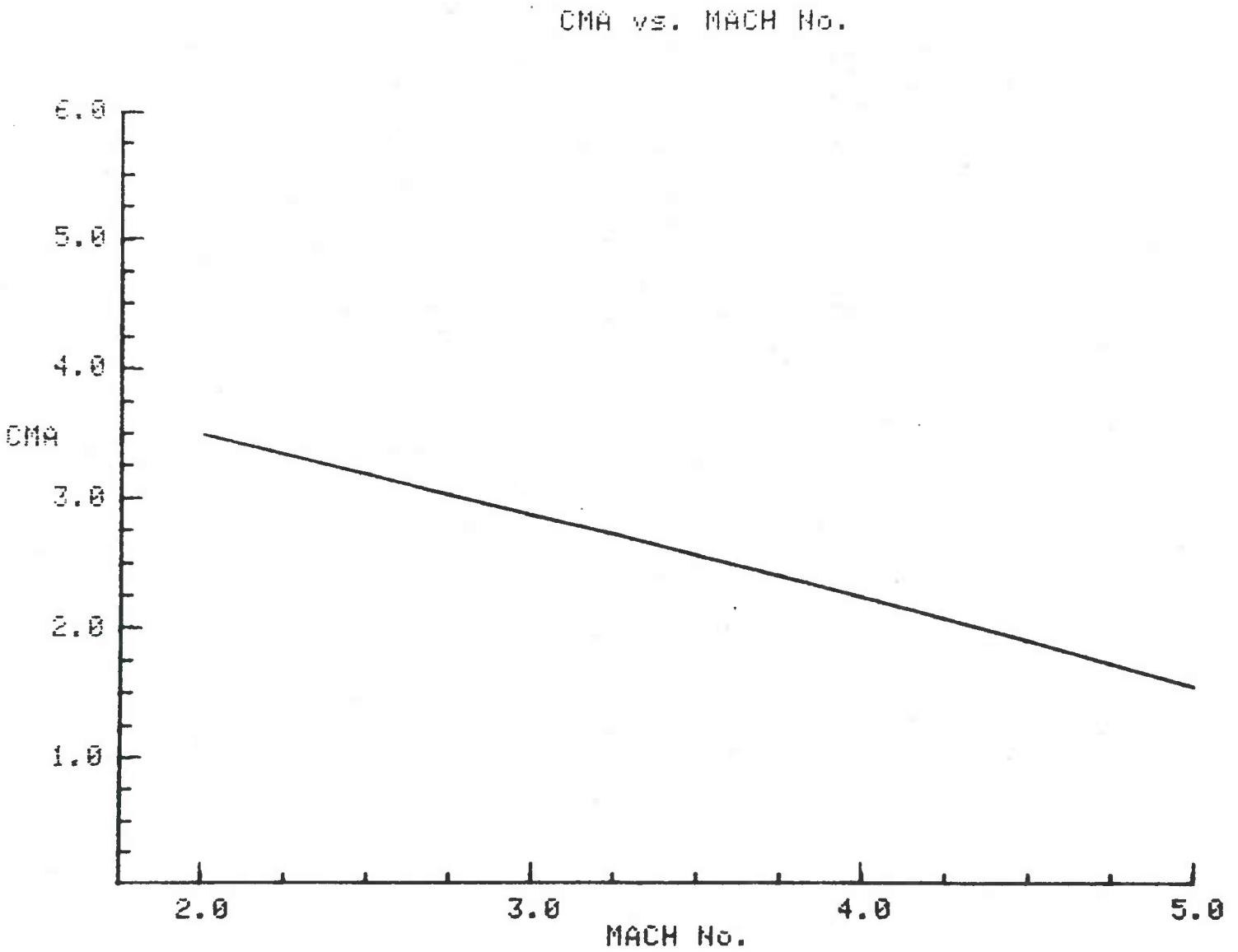
```
ALL VALUES ARE IN CALIBERS UNLESS OTHERWISE NOTED

B4      OGIVE LENGTH:  3.01
B5      OGIVE RADIUS: 18.86
D       CYLINDRICAL BODY LENGTH:  2.98
L6      CENTER OF GRAVITY OF PROJECTILE (NOSE):  3.60
B3      BOATTAIL LENGTH:  0.00
D2,D1   BOATTAIL ANGLE (DEGREES,MINUTES):  0.00
B6      ROTATING BAND RADIUS:  0.00
D3      ROTATING BAND WIDTH:  0.00
L7      DISTANCE TO ROTATING BAND FROM BASE:  0.00
L1      LENGTH OF BOOM EXTENTION:  0.00
A       PLOTTING DEVISE (1=PEN PLOTTER, 32=SCREEN):  32


DO YOU WISH TO CHANGE ANY DATA (Y OR N):
```

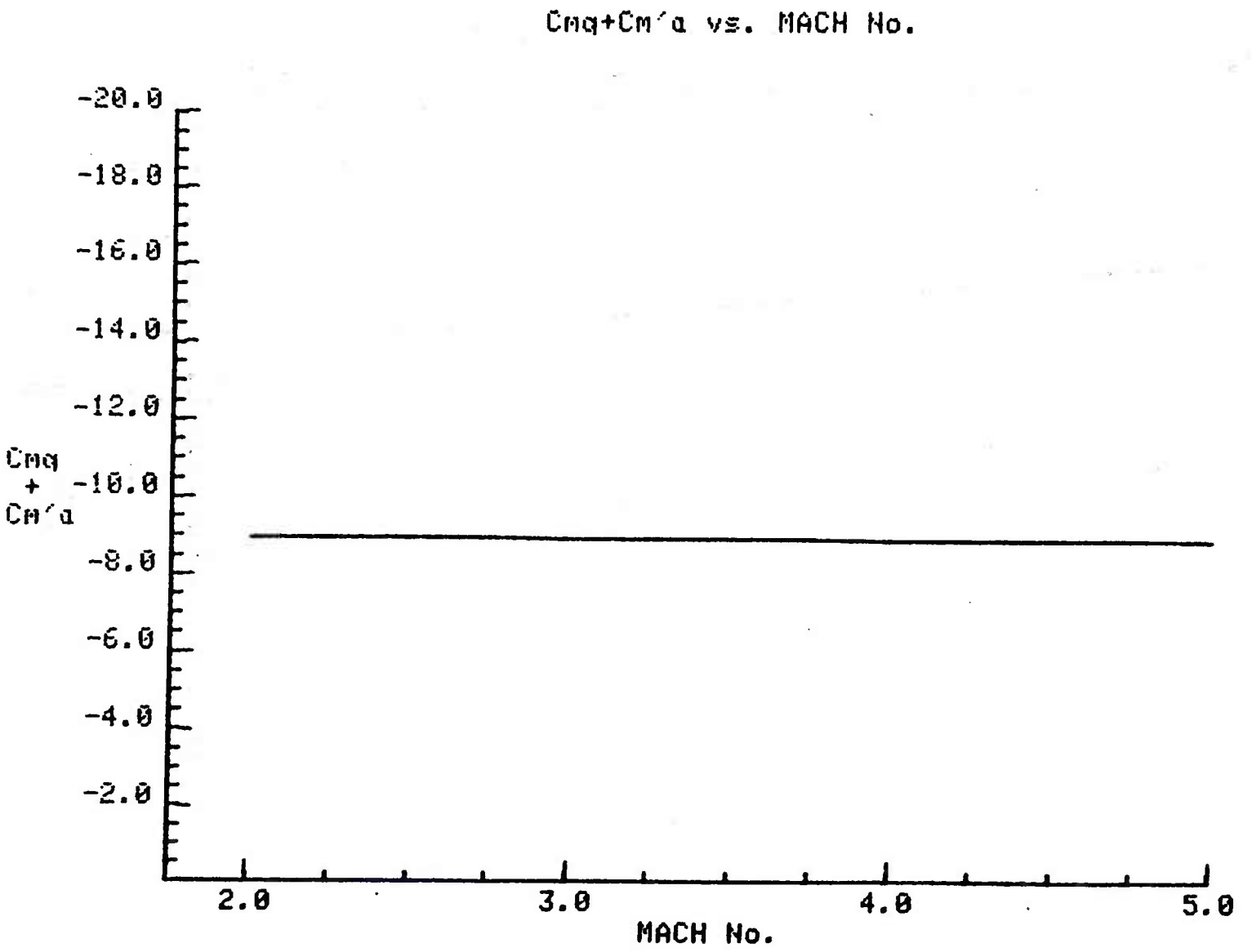
AERODYNAMIC COEFFICIENTS FOR SPIN STABILIZED PROJECTILES

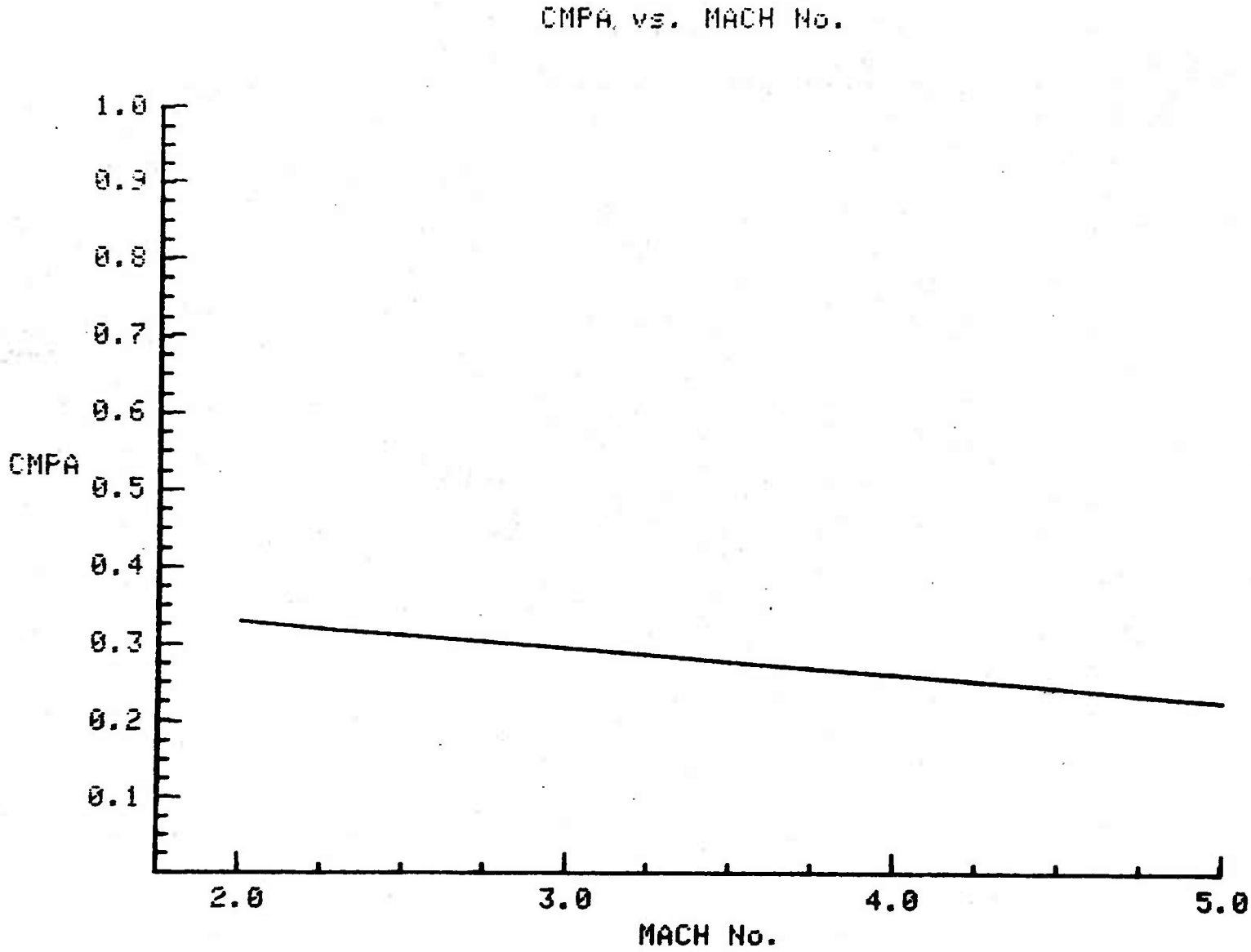
	MACH NUMBER						
	2.0	2.5	3.0	3.5	4.0	4.5	5.0
CDWB	0.159	0.141	0.128	0.118	0.110	0.103	0.098
CDVB	0.039	0.026	0.018	0.013	0.010	0.007	0.006
CDBB	0.093	0.083	0.073	0.063	0.053	0.043	0.033
CDRB	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CDT	0.290	0.250	0.219	0.194	0.172	0.153	0.136
CNASQ	3.036	3.209	3.380	3.552	3.726	3.905	4.087
CNABT	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CNABE	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CNAT	3.036	3.209	3.380	3.552	3.726	3.905	4.087
Cmq+Cm`q	-8.948	-8.933	-8.918	-8.903	-8.888	-8.872	-8.857
CMPA	0.328	0.311	0.294	0.277	0.260	0.243	0.226
CP(NOSE)	2.452	2.610	2.752	2.883	3.004	3.118	3.226
CMA	3.486	3.176	2.865	2.548	2.221	1.882	1.529


CDT vs. MACH No.
0.5
0.4
0.3
CDT
0.2
0.1
2.0
3.0
4.0
5.0
MACH No.

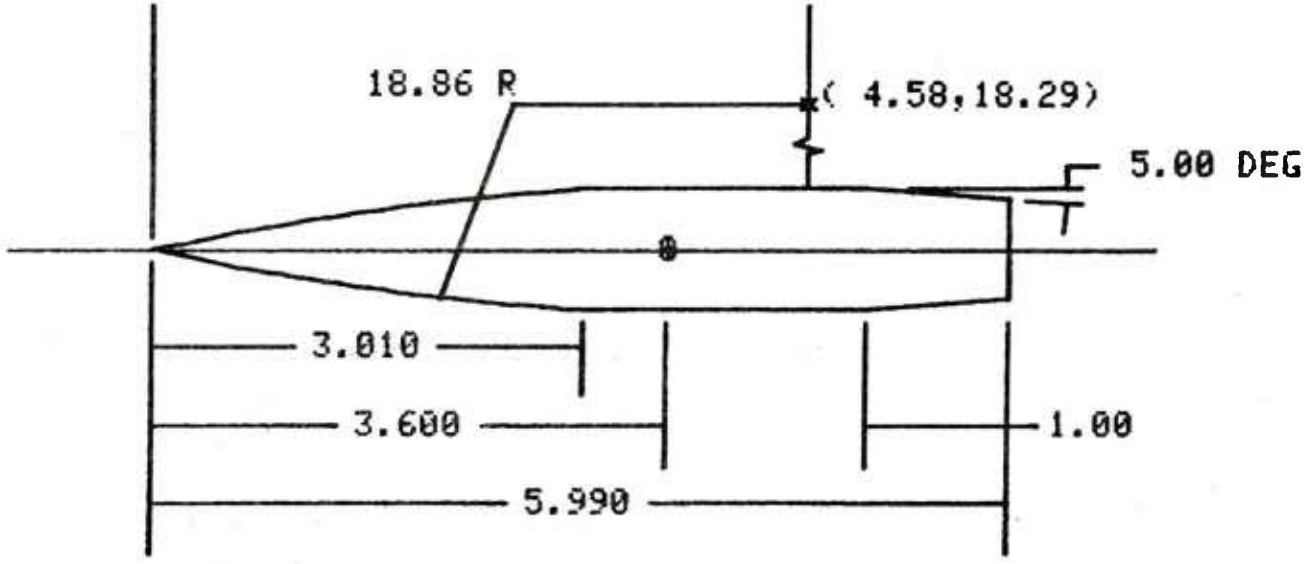

CNAT vs. MACH No.
6.0
5.0
4.0
CNAT
3.0
2.0
1.0
2.0
3.0
4.0
5.0
MACH No.


CMA vs. MACH No.
6.0
5.0
4.0
CMA
3.0
2.0
1.0
2.0
3.0
4.0
5.0
MACH No.


Cmq+Cm´α vs. MACH No.
-20.0
-18.0
-16.0
-14.0
-12.0
Cmq
+
Cm´α
-10.0
-8.0
-6.0
-4.0
-2.0
2.0
3.0
4.0
5.0
MACH No.


CMPA vs. MACH No.
CMPA
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
2.0
3.0
4.0
5.0
MACH No.

SECANT OGIVE CYLINDER BOATTAIL PROJECTILE DESIGN



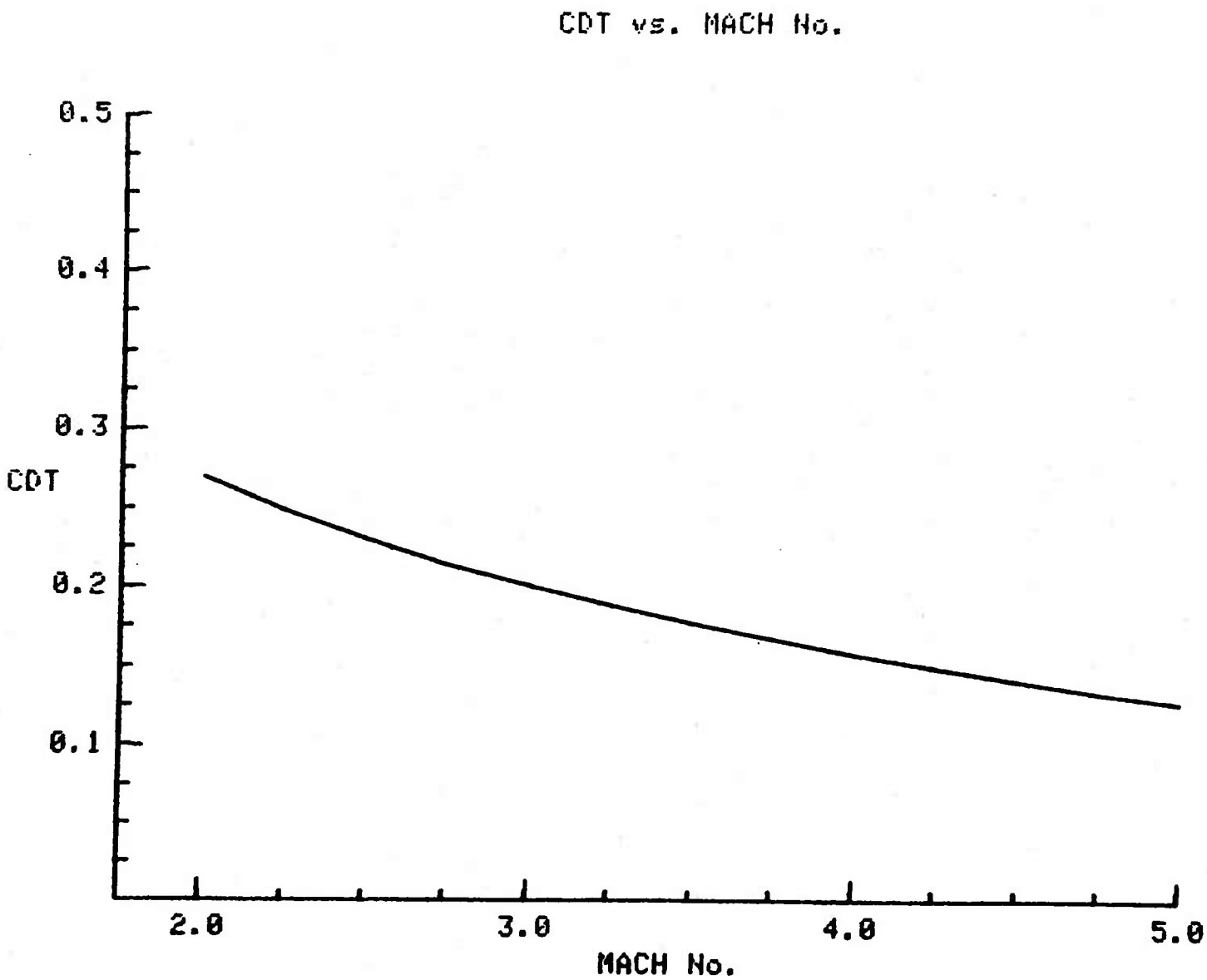
IF YOU WANT INITIAL DATA PRINTED OUT OR CHANGED ENTER 'Y':

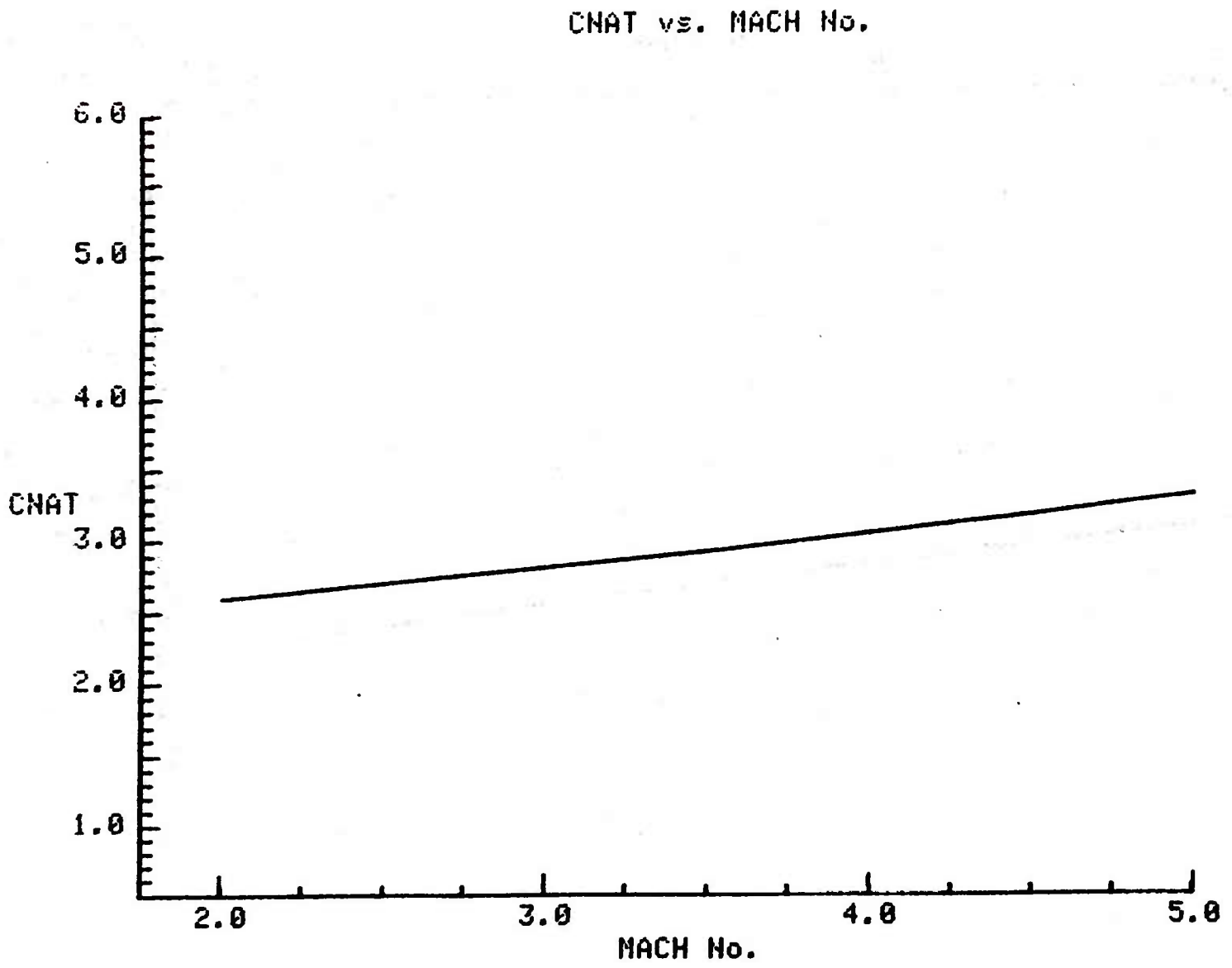
```
ALL VALUES ARE IN CALIBERS UNLESS OTHERWISE NOTED

B4      OGIVE LENGTH:  3.01
B5      OGIVE RADIUS: 18.86
D       CYLINDRICAL BODY LENGTH:  1.98
L6      CENTER OF GRAVITY OF PROJECTILE (NOSE):  3.60
B3      BOATTAIL LENGTH:  1.00
D2,D1   BOATTAIL ANGLE (DEGREES,MINUTES):  5.00
B6      ROTATING BAND RADIUS:  0.00
D3      ROTATING BAND WIDTH:  0.00
L7      DISTANCE TO ROTATING BAND FROM BASE:  0.00
L1      LENGTH OF BOOM EXTENTION:  0.00
A       PLOTTING DEVISE (1=PEN PLOTTER, 32=SCREEN):  32


DO YOU WISH TO CHANGE ANY DATA (Y OR N):
```

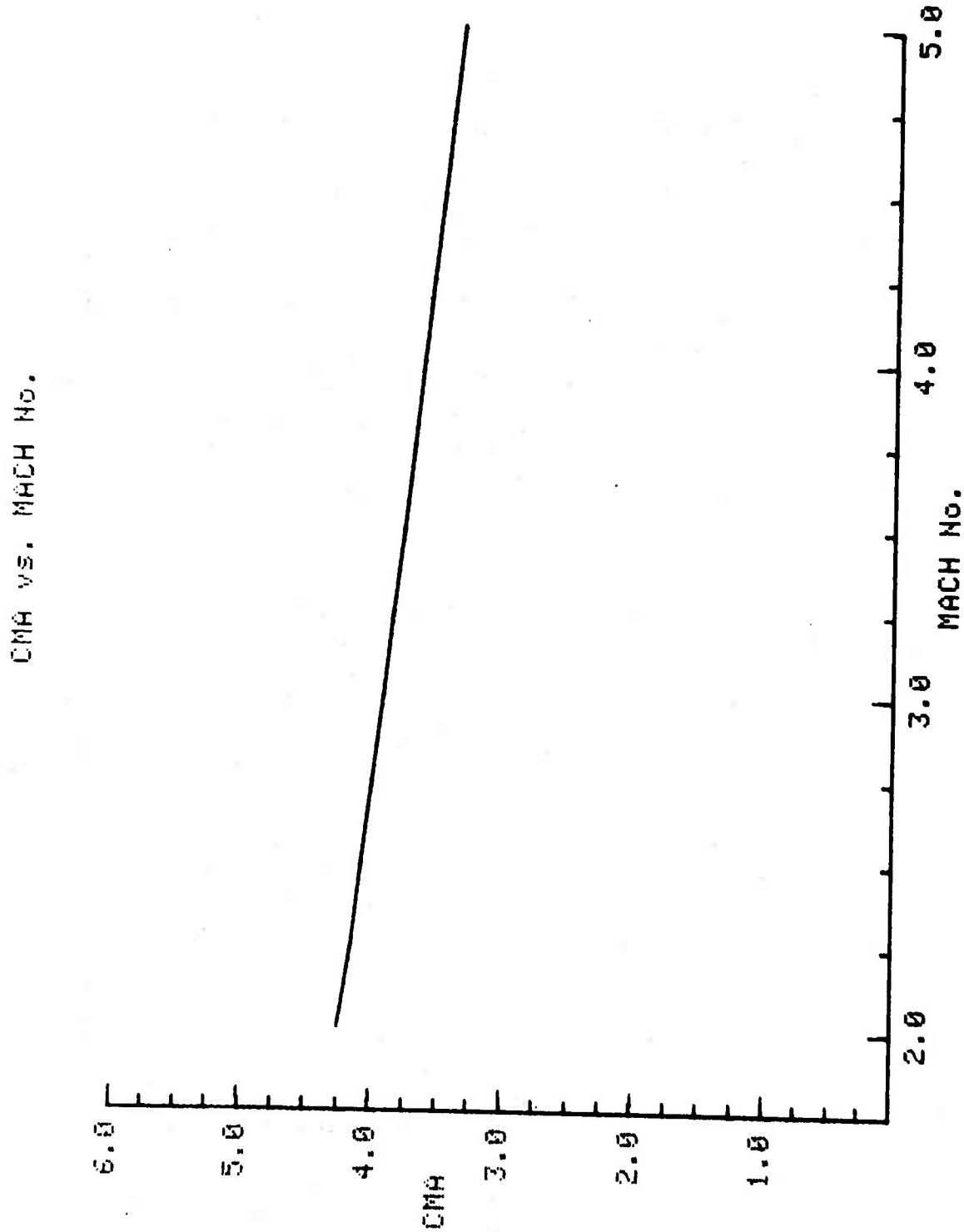
AERODYNAMIC COEFFICIENTS FOR SPIN STABILIZED PROJECTILES

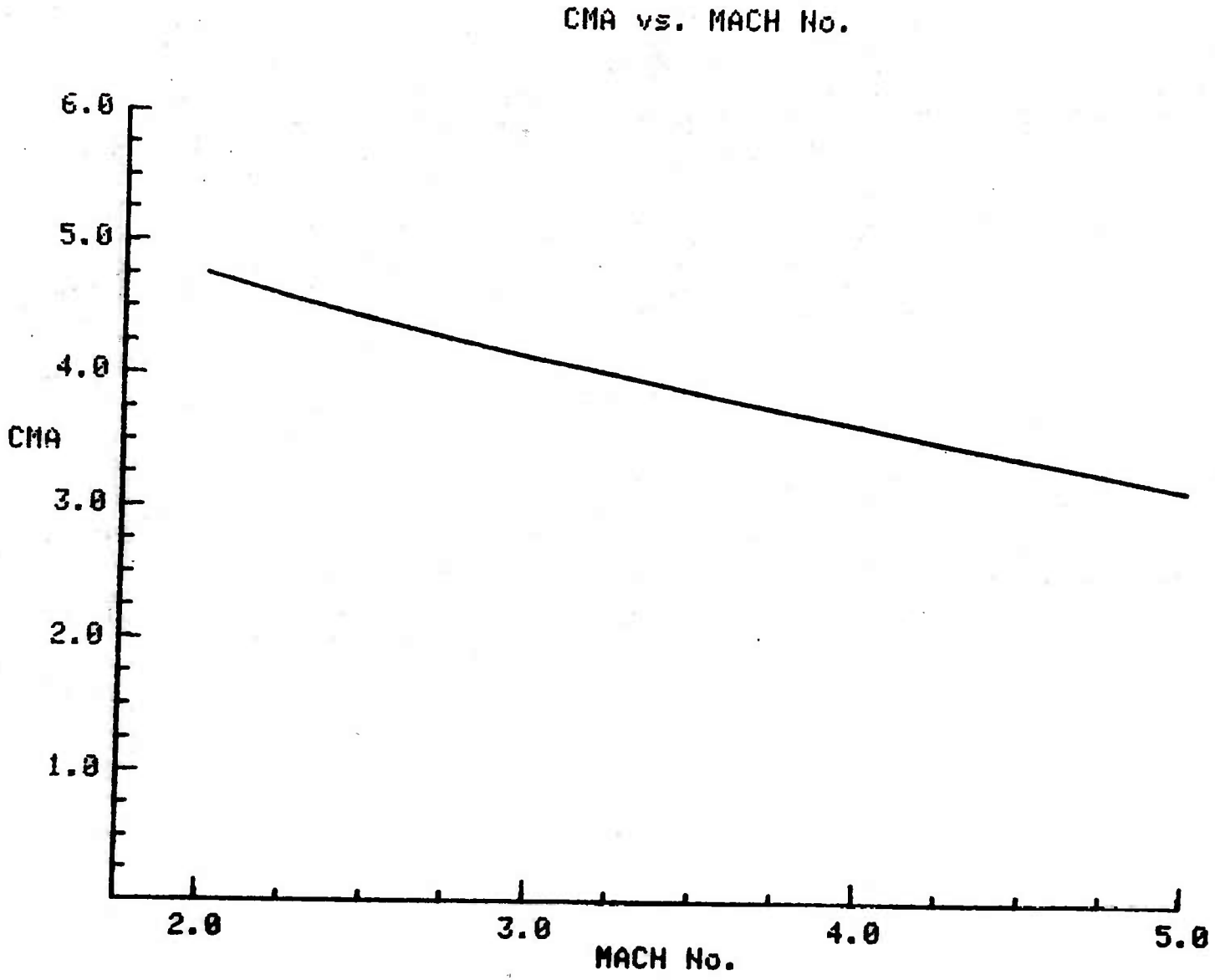
MACH NUMBER

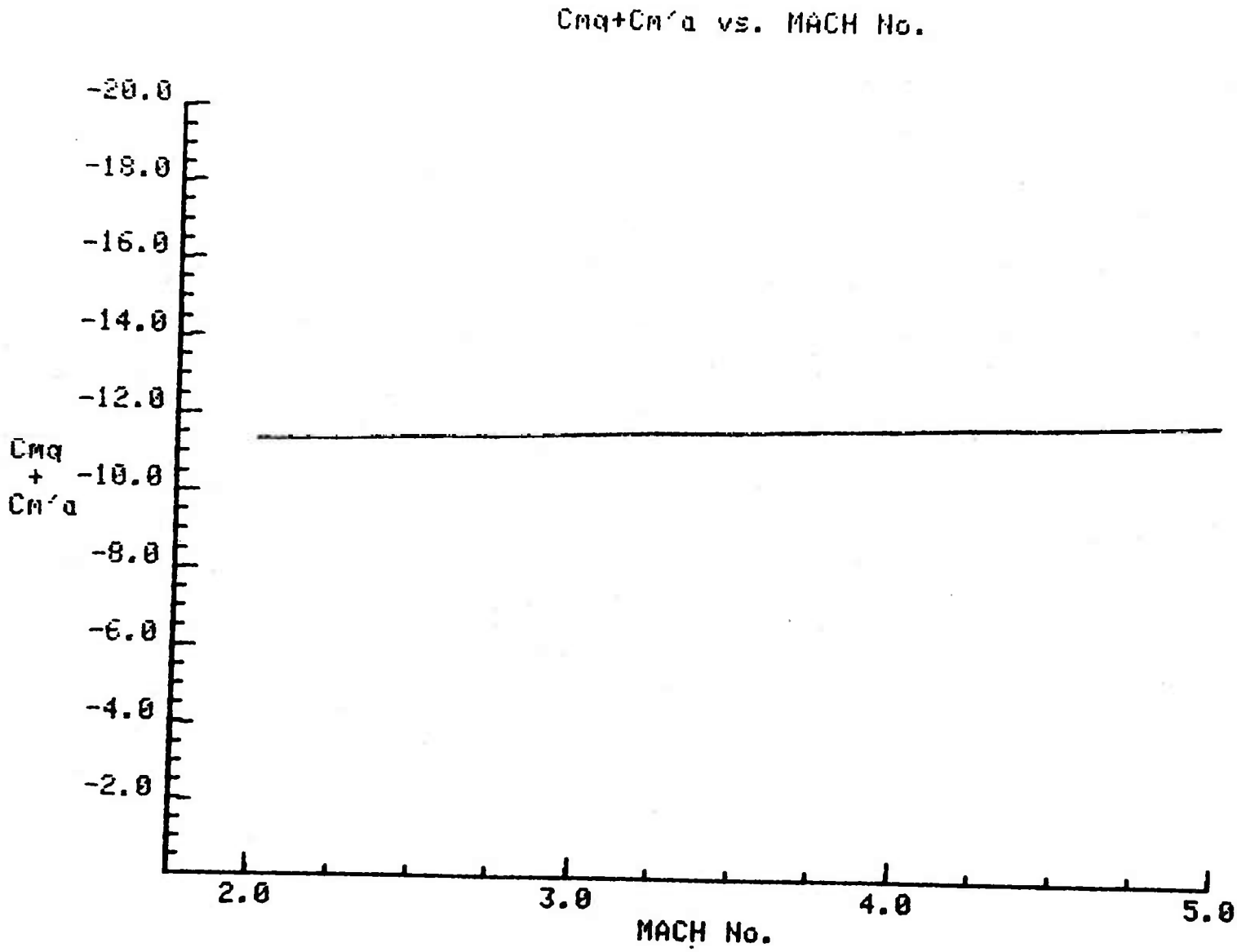
	2.0	2.5	3.0	3.5	4.0	4.5	5.0
CDWB	0.159	0.141	0.128	0.118	0.110	0.103	0.098
CDVB	0.048	0.033	0.023	0.016	0.012	0.009	0.007
CDBB	0.063	0.056	0.049	0.043	0.036	0.029	0.022
CDRB	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CDT	0.270	0.230	0.200	0.177	0.157	0.141	0.127
CNASQ	3.036	3.209	3.380	3.552	3.726	3.905	4.087
CNABT	2.601	2.705	2.814	2.928	3.049	3.177	3.312
CNABE	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CNAT	2.601	2.705	2.814	2.928	3.049	3.177	3.312
Cmq+Cm`a	-11.332	-11.436	-11.539	-11.642	-11.746	-11.849	-11.952
CMPA	0.382	0.364	0.346	0.328	0.310	0.292	0.274
CP(NOSE)	1.968	2.095	2.209	2.313	2.410	2.501	2.588
CMA	4.243	4.070	3.914	3.768	3.627	3.490	3.353

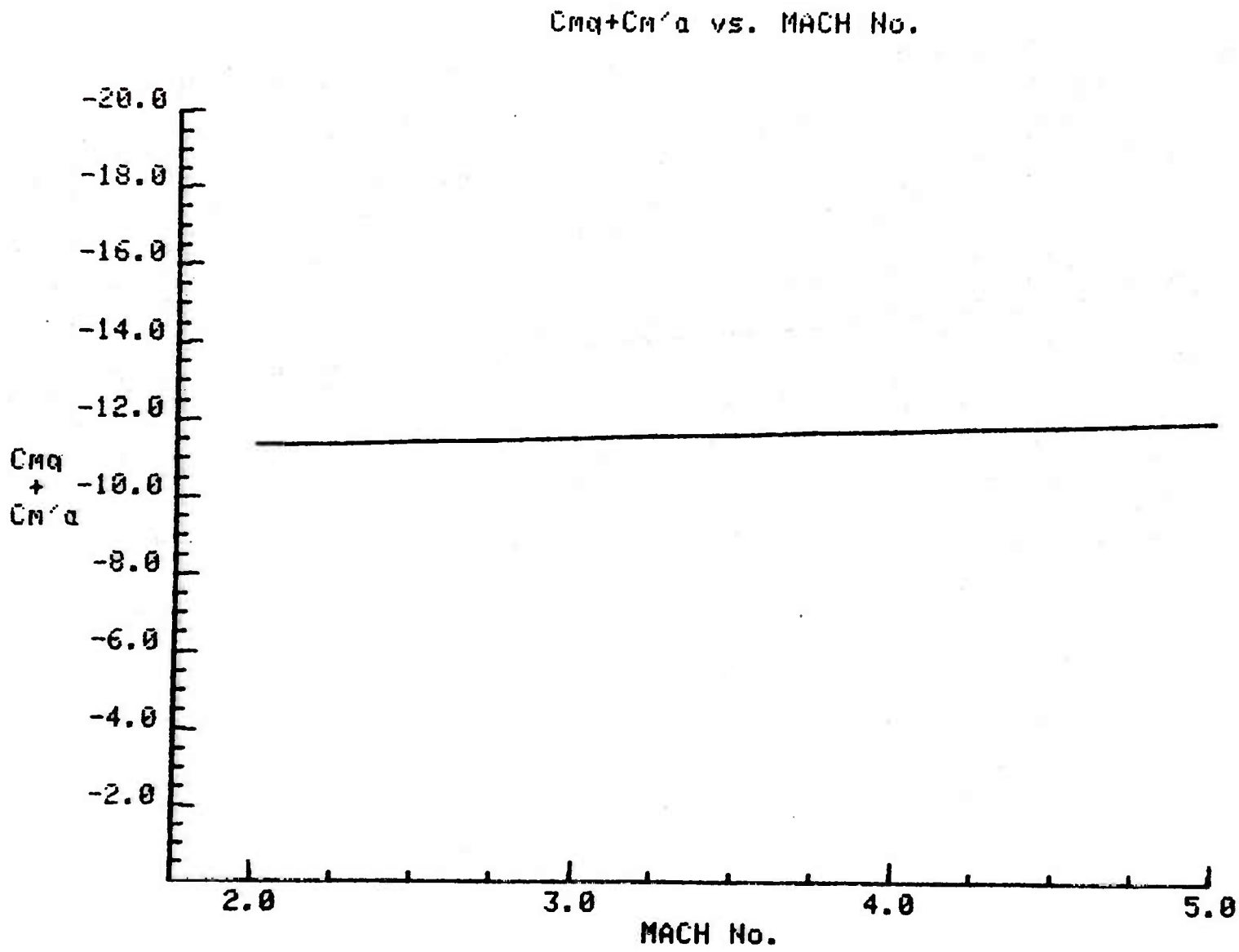

CDT vs. MACH No.
0.5
0.4
0.3
CDT
0.2
0.1
2.0
3.0
4.0
5.0
MACH No.

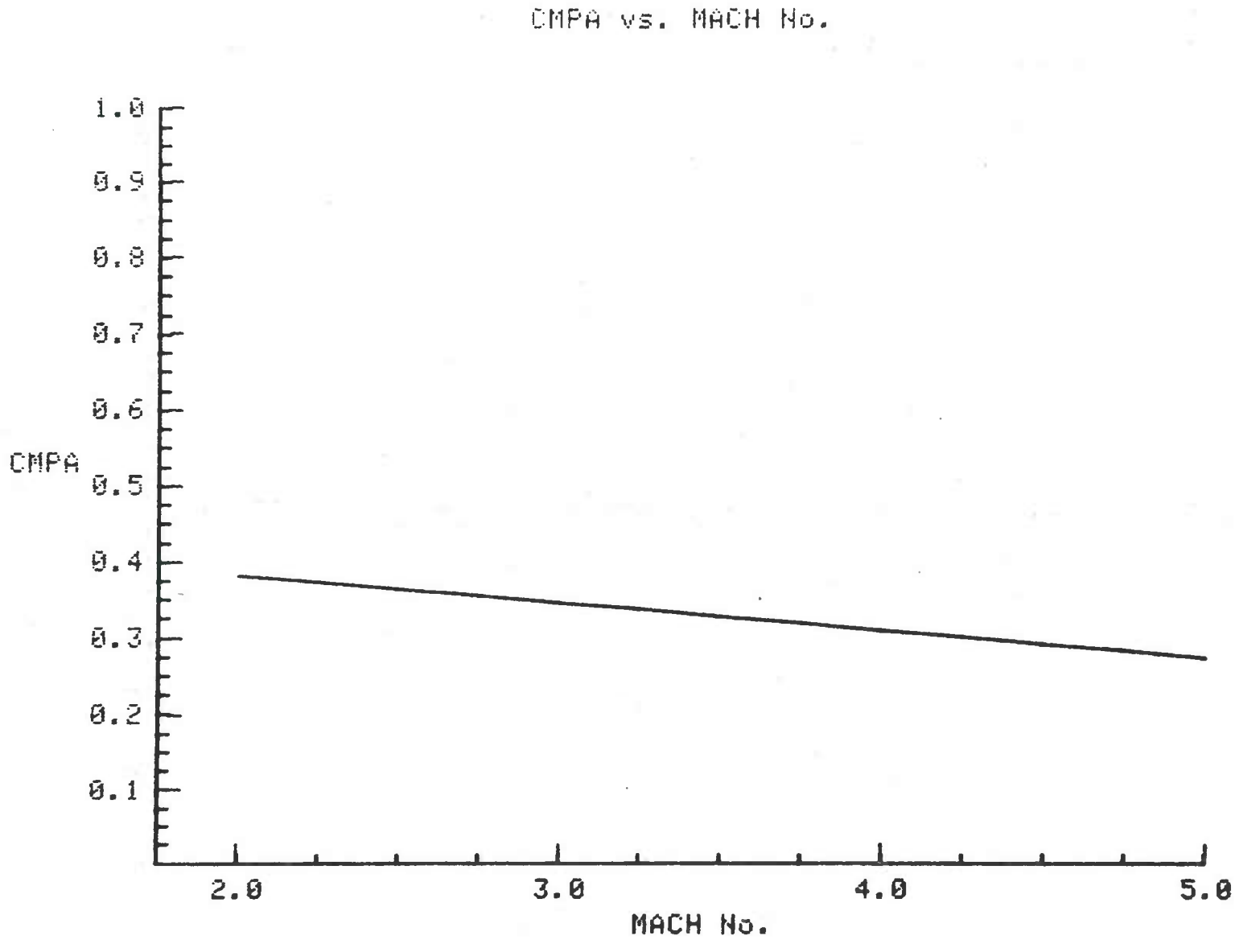

CNAT vs. MACH No.
6.0
5.0
4.0
CNAT
3.0
2.0
1.0
2.0
3.0
4.0
5.0
MACH No.


CMA vs. MACH No.
6.0
5.0
4.0
3.0
2.0
1.0
CMA
2.0
3.0
4.0
5.0
MACH No.

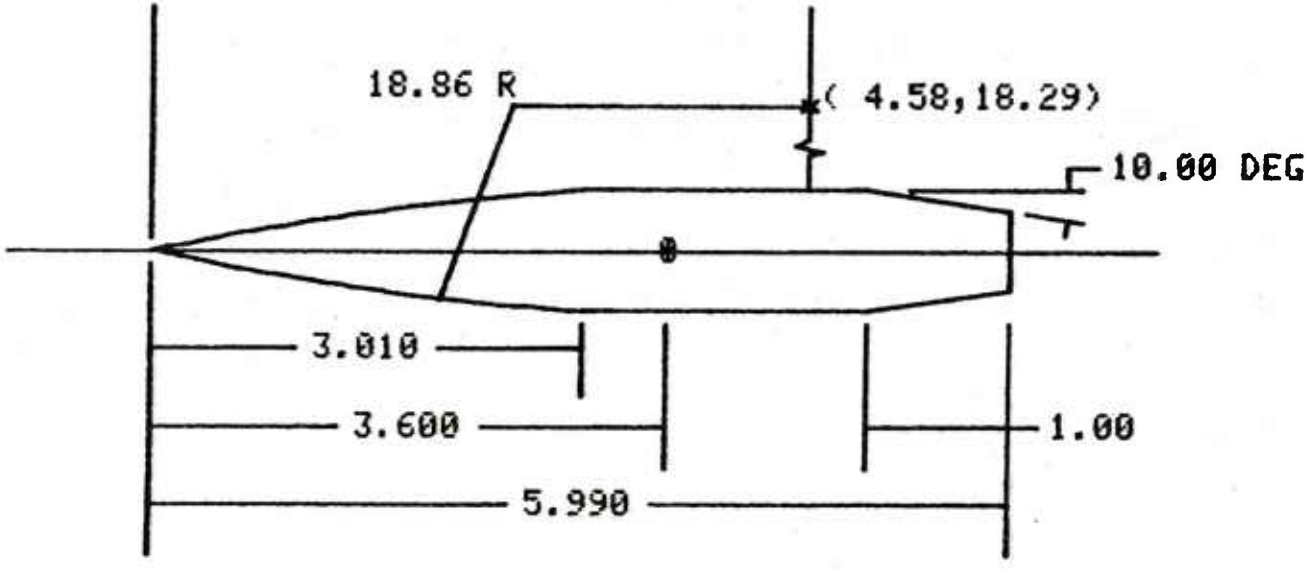

CMA vs. MACH No.
6.0
5.0
4.0
CMA
3.0
2.0
1.0
2.0
3.0
4.0
5.0
MACH No.


Cmq+Cm'α vs. MACH No.
-20.0
-18.0
-16.0
-14.0
-12.0
-10.0
-8.0
-6.0
-4.0
-2.0
Cmq + Cm'α
2.0
3.0
4.0
5.0
MACH No.


Cmq+Cm'α vs. MACH No.
-20.0
-18.0
-16.0
-14.0
-12.0
-10.0
-8.0
-6.0
-4.0
-2.0
Cmq + Cm'α
2.0
3.0
4.0
5.0
MACH No.


CMPA vs. MACH No.
1.0
0.9
0.8
0.7
0.6
CMPA
0.5
0.4
0.3
0.2
0.1
2.0
3.0
4.0
5.0
MACH No.

SECANT OGIVE CYLINDER BOATTAIL PROJECTILE DESIGN

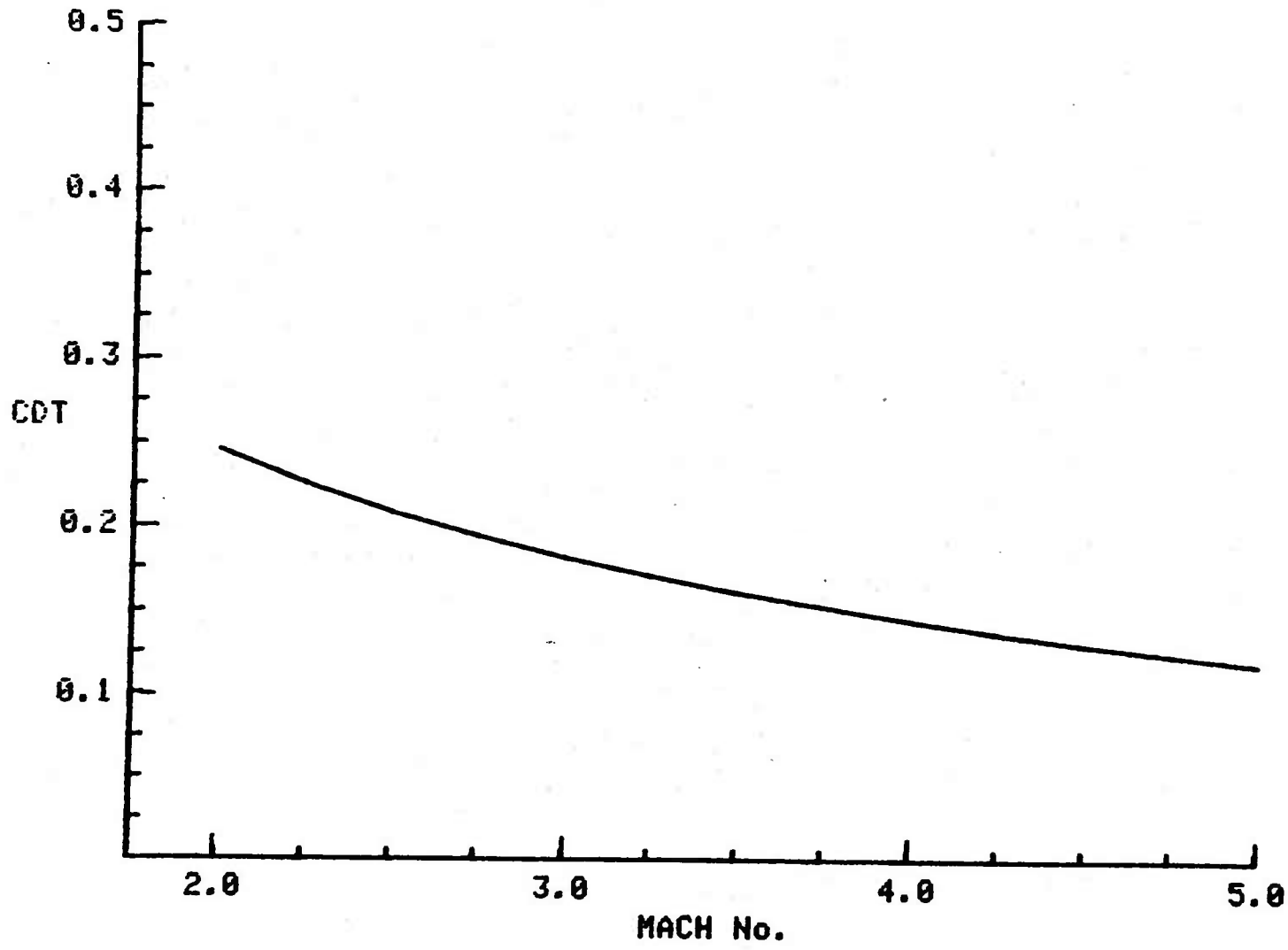


IF YOU WANT INITIAL DATA PRINTED OUT OR CHANGED ENTER 'Y':

```
ALL VALUES ARE IN CALIBERS UNLESS OTHERWISE NOTED

B4   OGIVE LENGTH:  3.01
B5   OGIVE RADIUS: 18.86
D    CYLINDRICAL BODY LENGTH:  1.98
L6   CENTER OF GRAVITY OF PROJECTILE (MEASURED FROM NOSE):  3.60
B3   BOATTAIL LENGTH:  1.00
D6   BOATTAIL ANGLE (DEGREES): 10.00
B6   ROTATING BAND RADIUS:  0.00
D3   ROTATING BAND WIDTH:  0.00
L7   DISTANCE TO ROTATING BAND FROM BASE:  0.00
L1   LENGTH OF BOOM EXTENTION:  0.00
A    PLOTTING DEVISE (1=PEN PLOTTER, 32=SCREEN):  32



DO YOU WISH TO CHANGE ANY DATA (Y OR N):
```

AERODYNAMIC COEFFICIENTS FOR SPIN STABILIZED PROJECTILES

	MACH NUMBER						
	2.0	2.5	3.0	3.5	4.0	4.5	5.0
CDWB	0.159	0.141	0.128	0.118	0.110	0.103	0.098
CDVB	0.048	0.033	0.023	0.016	0.012	0.009	0.007
CDBB	0.039	0.035	0.030	0.026	0.022	0.018	0.014
CDRB	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CDT	0.246	0.208	0.181	0.160	0.144	0.130	0.118
CNASQ	3.036	3.209	3.380	3.552	3.726	3.905	4.087
CNABT	2.601	2.705	2.814	2.928	3.049	3.177	3.312
CNABE	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CNAT	2.601	2.705	2.814	2.928	3.049	3.177	3.312
Cmq+Cm`a	-11.332	-11.436	-11.539	-11.642	-11.746	-11.849	-11.952
CMPA	0.382	0.364	0.346	0.328	0.310	0.292	0.274
CP(NOSE)	1.976	2.102	2.216	2.320	2.417	2.508	2.595
CMA	4.224	4.051	3.894	3.747	3.606	3.467	3.329


CDT vs. MACH No.
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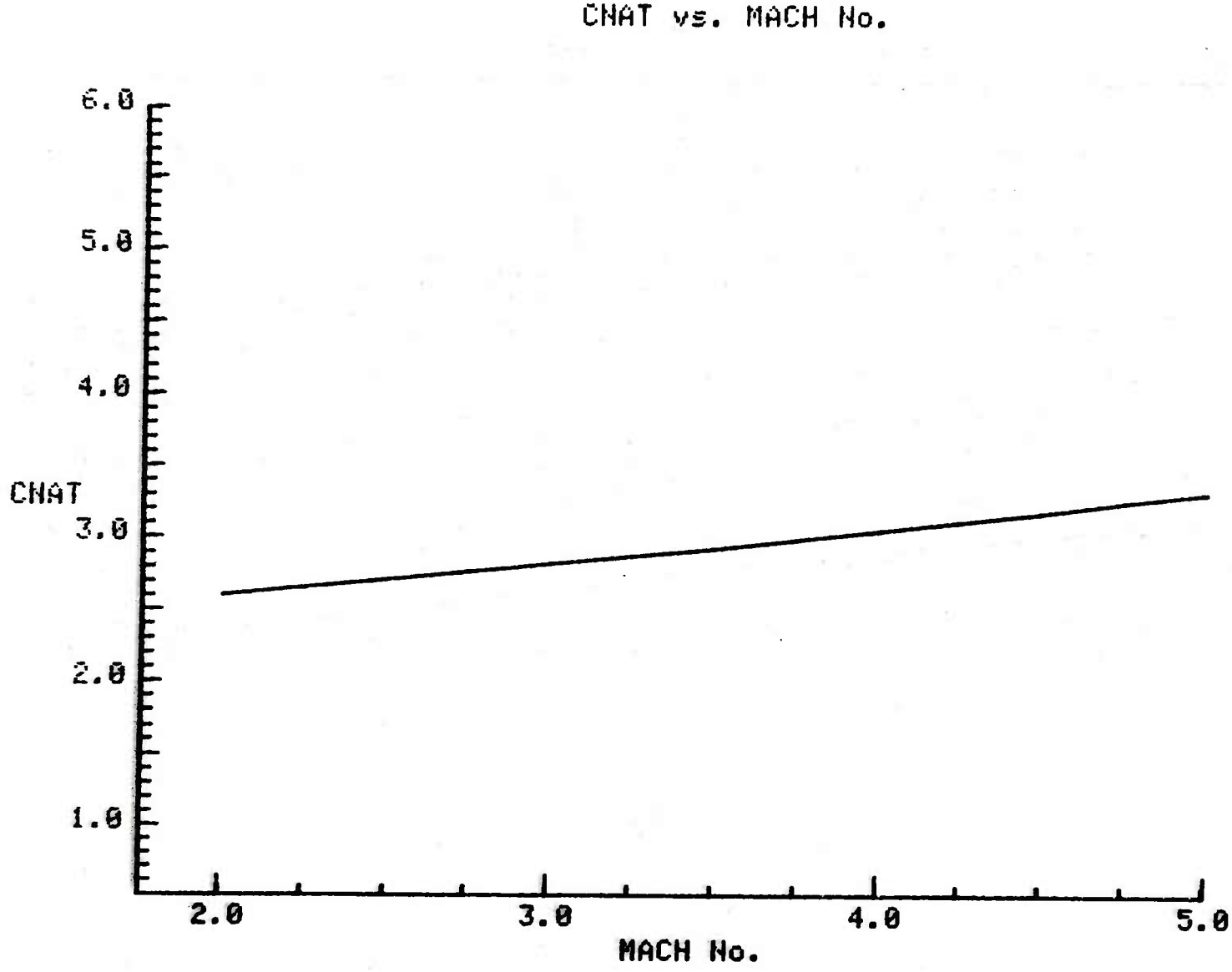
0.4
0.3
CDT
0.2
0.1
2.0
3.0
4.0
5.0
MACH No.


CNAT vs. MACH No.
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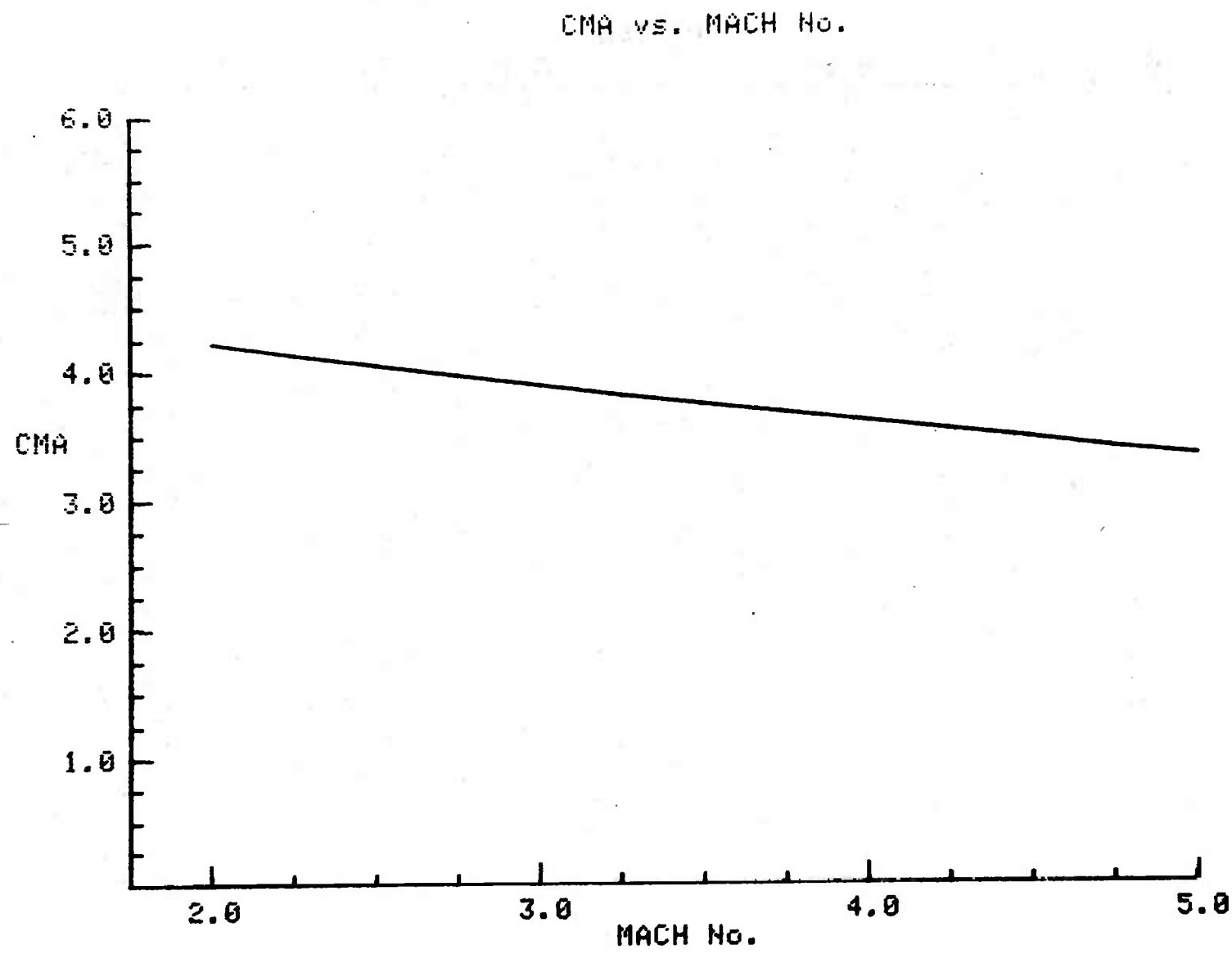
5.0
4.0
CNAT
3.0
2.0
1.0
2.0
3.0
4.0
5.0
MACH No.


CMA vs. MACH No.
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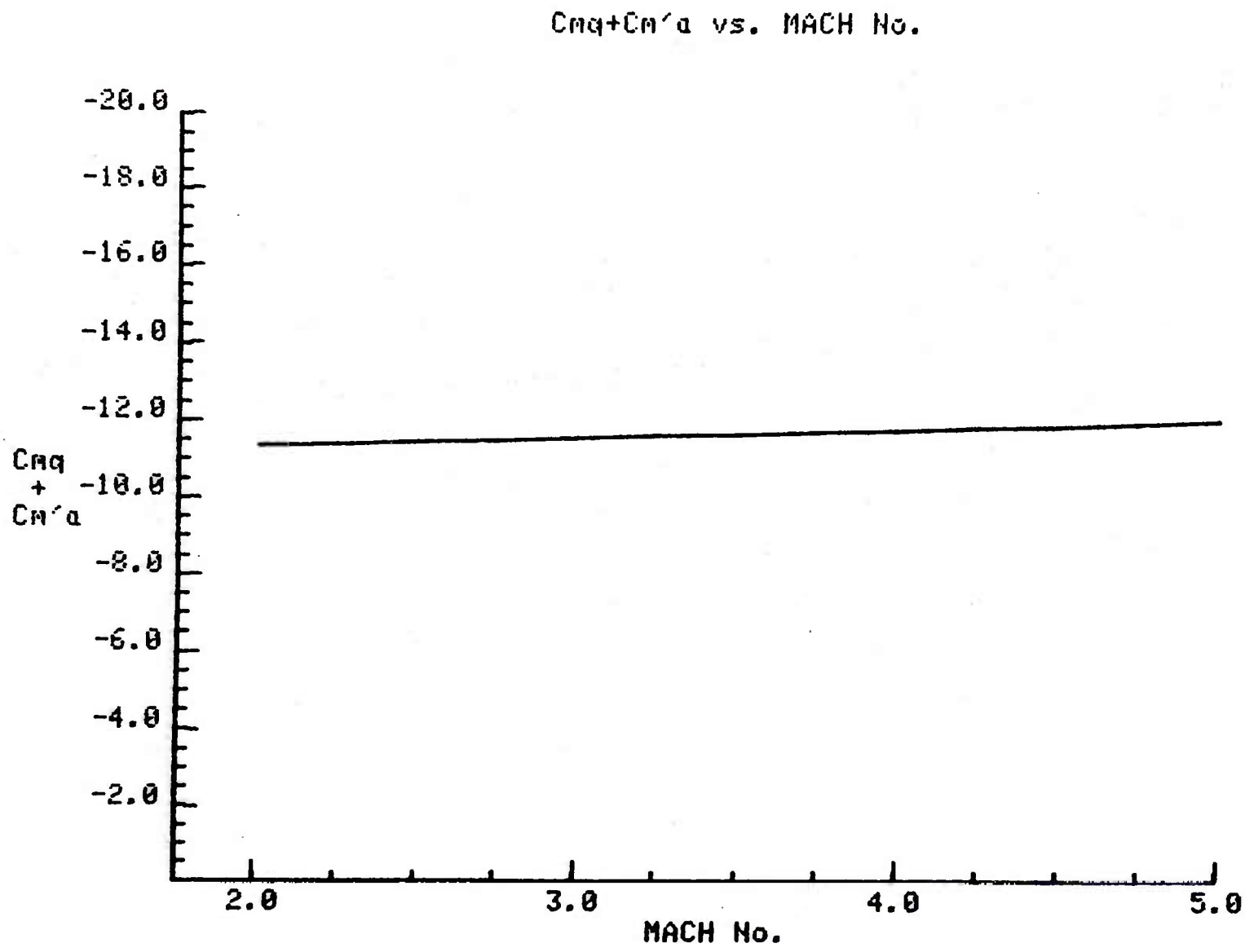
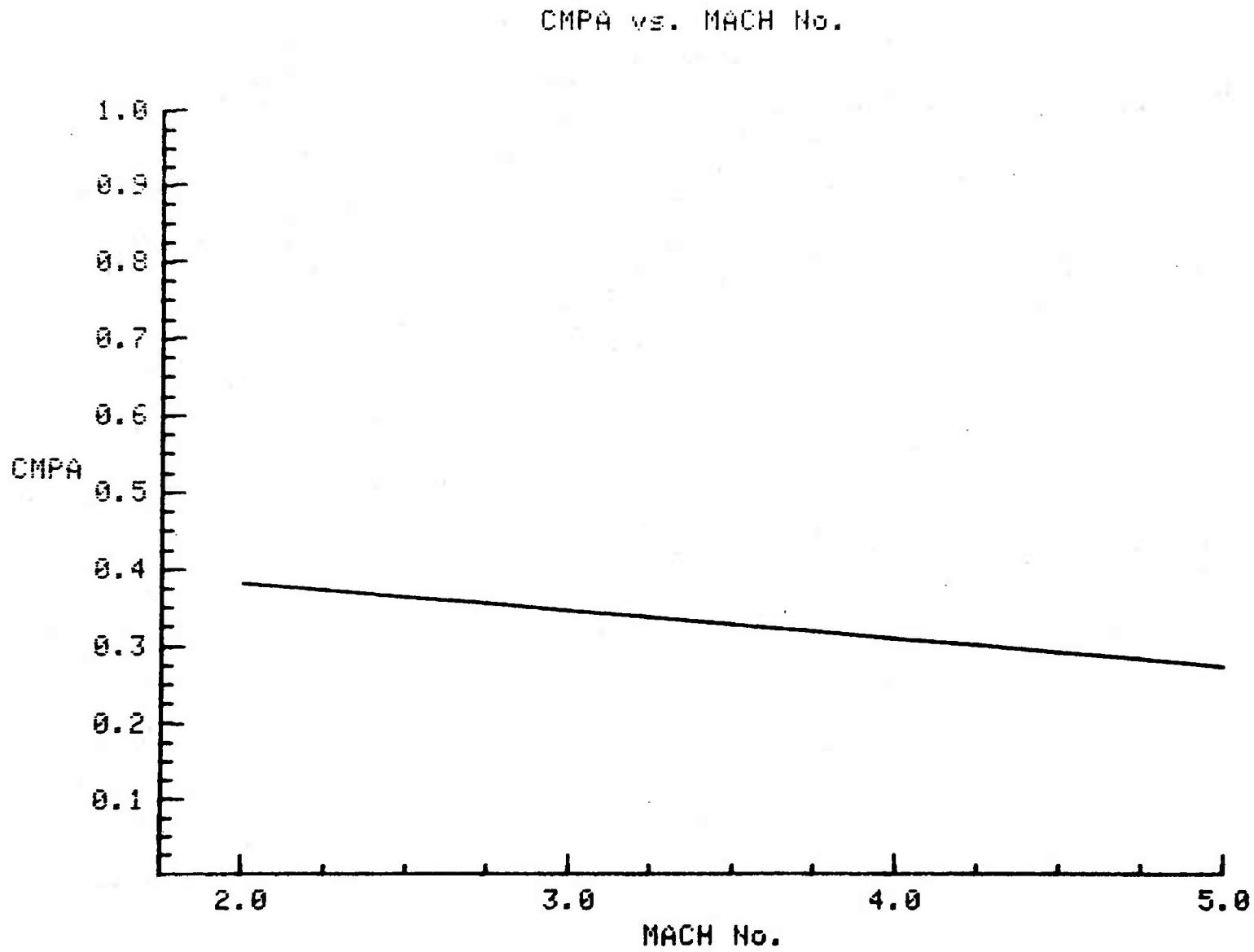
4.0
CMA
3.0
2.0
1.0
2.0
3.0
4.0
5.0
MACH No.


Cmq+Cm'a vs. MACH No.
-20.0
-18.0
-16.0
-14.0
-12.0
-10.0
-8.0
-6.0
-4.0
-2.0
Cmq
+
Cm'a
2.0
3.0
4.0
5.0
MACH No.


CMPA vs. MACH No.
CMPA
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
2.0
3.0
4.0
5.0
MACH No.

LIST OF SYMBOLS

b	Intercept of C_D vs M characteristic
c	Slope of C_D vs M characteristic
c.g.	Center of gravity of projectile
c.p.	Center of pressure of normal force
d	1.0 caliber, reference diameter
ℓ_a	Afterbody length
ℓ_{bt}	Boattail length
ℓ_n	Nose length
ℓ_{rot}	Length of rotating band moment arm
ℓ_{ext}	Length of base extension
m	Mass of projectile
p	Rotation rate
$\frac{p\,d}{v}$	Nondimensional spin rate
q,u	Transverse angular velocities
q_t	$(q^2 + u^2)^{\frac{1}{2}}$
r_b	Radius of face of base
s	Range
v	Velocity of projectile
v_{sonic}	Sonic velocity of ambient atmosphere
$x_{c.g.}$	Distance from nose to center of gravity
$x_{c.p.}$	Distance from nose to center of pressure of normal force
A_{ref}	Reference area, (.785 cal)
C_D	$\frac{\text{Drag Force}}{\frac{1}{2}\rho v^2 A_{ref}}$
C_{DBB}	Pressure drag coefficient, - base of body
C_{DRB}	Rotating band drag coefficient

C_{DVB} Viscous drag coefficient - body

C_{DWB} Wave drag coefficient - body (nose)

C_{DT} Total drag coefficient

$C_{M\alpha}$ $\dfrac{\text{Static Moment}}{\frac{1}{2}\rho v^2 A_{ref} d \delta}$, aerodynamic moment slope coefficient

$C_{M\alpha(ext)}$ Aerodynamic moment slope with base extension

$C_{Mp\alpha}$ $\dfrac{\text{Magnus Moment}}{\frac{1}{2}\rho v^2 A_{ref} (\frac{pd}{v}) \delta}$, Magnus moment slope coefficient; moment rotates nose $\perp$ to plane of α_T in direction of spin.

$C_{Mq}+C_{M\dot{\alpha}}$ $\dfrac{\text{Damping Moment}}{\frac{1}{2}\rho v^2 A_{ref} d(\frac{q_t d}{v})}$, damping moment slope coefficient; moment increases angular velocity

$C_{N\alpha}$ $\dfrac{\text{Normal Force}}{\frac{1}{2}\rho v^2 A_{ref} \delta}$, normal force slope coefficient

$C_{N\alpha(bt)}$ Normal force slope coefficient for projectiles with boattails.

$C_{N\alpha(ext)}$ Normal force slope coefficient for projectiles with base extensions.

I_x Axial mass moment of inertia

I_y Transverse mass moment of inertia

M Mach number

M_O Mach number at muzzle

P Operational parameter, $\dfrac{cM_O + b}{M_O}$

Q Operational parameter, $\dfrac{\rho A_{ref} b}{2m}$

R Ogive nose radius

α, β Angle of attack, sideslip (employed as a directional subscript)

α_t $(\alpha^2 + \beta^2)^{\frac{1}{2}}$, total angle of attack

$\dot{\alpha}$ Rate of change of α

ρ Air density

δ Sine α_t

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